CITY OF FISHERS STORMWATER TECHNICAL STANDARDS MANUAL

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Chapter One

INTRODUCTION

This document contains formulas and methodologies for the review and design of both stormwater quantity and stormwater quality facilities. Chapters 2 through 6 contain stormwater conveyance and detention calculations and requirements. Chapter 7 contains information on erosion control requirements and other pollution prevention measures for active construction sites. Chapters 8 covers the [post-construction water quality standards and calculations required to properly size and design stormwater quality features that will treat runoff long-term following construction completion. This includes both Conventional and Low Impact Development (LID) approaches. Chapter 9 contains miscellaneous standards regarding grading and building pad elevations, acceptable outlet and adjoining property impact policies, no net loss floodplain storage policy, and policy on dams and levees. A comprehensive glossary of terms is provided in Appendix A. Appendix B contains several useful and necessary standard forms. Best Management Practices (BMPs) for erosion control measures during the construction phase are contained in Appendix C. It is the intent of the City that material presented in Appendices C will be revised or eliminated once the Indiana Storm Water Quality Manual (ISWQM) is updated to include details regarding the BMPs currently included in Appendix C. Appendix D contains non-structural and structural post-construction BMP Fact Sheets as well as Recommended Plant Lists, Recommended Materials, Soil Infiltration Testing Protocol, BMP Maintenance Checklists, and a Maintenance Agreement for post-construction BMPs.

The City of Fishers also maintains a number of standard design drawings called the City of Fishers Standard Construction Details that must be followed by the applicants for the design of stormwater management facilities. In case of discrepancy between these standard drawings and other requirements contained in this document or the Resolution, the most restrictive requirement shall apply.

The site designer is encouraged to review the LID discussion in Chapter 8 prior to the site design to take advantage of runoff reduction recognitions provided towards water quantity calculations if LID practices are utilized as part of the site design.

Chapter Two

METHODOLOGY FOR DETERMINATION OF RUNOFF RATES

Runoff rates shall be computed for the area of the parcel under development plus the area of the watershed flowing into the parcel under development. The rate of runoff which is generated as the result of a given rainfall intensity may be calculated as follows:

A. Development Sites Less than or Equal to 5 Acres in Size, With a Contributing Drainage Area Less than or Equal to 25 Acres and No Depressional Storage

The Rational Method may be used. A computer model, such as TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE), that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies may also be used along with a 24-hour duration NRCS Type 2 storm. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

LID Exception: If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 8 (Post-Construction Stormwater Quality Management Standards), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 8 and BMP fact sheets may be determined based on pre-development underlying soil layer.

In the Rational Method, the peak rate of runoff, Q, in cubic feet per second (cfs) is computed as:

$$\mathbf{Q = CIA}$$

Where: C = Runoff coefficient, representing the characteristics of the drainage area and defined as the ratio of runoff to rainfall.

I = Average intensity of rainfall in inches per hour for a duration equal to the time of concentration (t_c) for a selected rainfall frequency.

A = Tributary drainage area in acres.

Values for the runoff coefficient "C" are provided in **Tables 2-1** and **2-2**, which show values for different types of surfaces and local soil characteristics. The composite "C" value used for a given drainage area with various surface types shall be the weighted average value for the total area calculated from a breakdown of individual areas having different surface types. **Table 2-3** provides runoff coefficients and inlet times for different land use classifications.

Rainfall intensity shall be determined from the rainfall frequency data shown in **Table 2-4**.

In general, the time of concentration (t_c) methodology to be used for all stormwater management projects within City of Fishers shall be as outlined in the U.S. Department of Agriculture (USDA) - NRCS TR-55 Manual. In urban or developed areas, the methodology to be used shall be the sum of the inlet time and flow time in the stormwater facility from the most remote part of the drainage area to the point under consideration. The flow time in the storm sewers may be estimated by the distance in feet divided by velocity of flow in feet per second. The velocity shall be determined by the Manning's Equation (see Chapter 4). Inlet time is the combined time required for the runoff to reach the inlet of the storm sewer. It includes overland flow time and flow time through established surface drainage channels such as swales, ditches, and sheet flow across such areas as lawns, fields, and other graded surfaces.

TABLE 2-1

Urban Runoff Coefficients				
Type of Surface	*Runoff Coefficient "C" (by Storm Recurrence Interval)*			
	< 25 year	*25 year*	*50 year*	*100 year*
◆ **Hard Surfaces**				
Asphalt	0.82	0.90	1.00	1.00
Concrete	0.85	0.94	1.00	1.00
Roof	0.85	0.94	1.00	1.00
◆ **Lawns** (Sandy)				
Flat (0-2% Slope)	0.07	0.08	0.09	0.12
Rolling (2-7% Slope)	0.12	0.13	0.16	0.20
Steep (Greater than 7% Slope)	0.17	0.19	0.22	0.28
◆ **Lawns** (Clay)				
Flat (0-2% Slope)	0.16	0.18	0.21	0.26
Rolling (2-7% Slope)	0.21	0.23	0.28	0.35
Steep (Greater than 7% Slope)	0.30	0.33	0.40	0.50

Source: HERPICC Stormwater Drainage Manual, July 1995.

TABLE 2-2

Rural Runoff Coefficients				
Type of Surface	*Runoff Coefficient "C" (by Storm Recurrence Interval)*			
	< 25 year	*25 year*	*50 year*	*100 year*
◆ **Woodland** (Sandy)				
Flat (0-2% Slope)	0.10	0.11	0.13	0.17
Rolling (2-7% Slope)	0.25	0.28	0.33	0.41
Steep (Greater than 7% Slope)	0.30	0.33	0.40	0.50
◆ **Woodland** (Clay)				
Flat (0-2% Slope)	0.30	0.33	0.40	0.50
Rolling (2-7% Slope)	0.35	0.39	0.46	0.58
Steep (Greater than 7% Slope)	0.50	0.55	0.66	0.83
◆ **Pasture** (Sandy)				
Flat (0-2% Slope)	0.10	0.11	0.13	0.17
Rolling (2-7% Slope)	0.16	0.18	0.21	0.26
Steep (Greater than 7% Slope)	0.22	0.24	0.29	0.36
◆ **Pasture** (Clay)				
Flat (0-2% Slope)	0.30	0.33	0.40	0.50
Rolling (2-7% Slope)	0.36	0.40	0.48	0.59
Steep (Greater than 7% Slope)	0.42	0.46	0.55	0.69
◆ **Cultivated** (Sandy)				
Flat (0-2% Slope)	0.30	0.33	0.40	0.50
Rolling (2-7% Slope)	0.40	0.44	0.53	0.66
Steep (Greater than 7% Slope)	0.52	0.57	0.69	0.86
◆ **Cultivated** (Clay)				
Flat (0-2% Slope)	0.50	0.55	0.66	0.83
Rolling (2-7% Slope)	0.60	0.66	0.79	0.99
Steep (Greater than 7% Slope)	0.72	0.79	0.95	1.00

Source: HERPICC Stormwater Drainage Manual, July 1995.

TABLE 2-3

Runoff Coefficients by Land Use, Typical Inlet Times, and Storm Recurrence Interval													
Land Use	*Runoff Coefficients "C" (by Storm Recurrence Interval)*												*Inlet Time (Minutes) (4)*
	Flat (1)				Rolling (2)				Steep (3)				
	< 25 year	*25 year*	*50 year*	*100 year*	*< 25 year*	*25 year*	*50 year*	*100 year*	*< 25 year*	*25 year*	*50 year*	*100 year*	
Commercial *(CBD)*	0.75	0.83	0.99	1.00	0.83	0.91	1.00	1.00	0.91	1.00	1.00	1.00	5
Commercial *(Neighborhood)*	0.54	0.59	0.71	0.89	0.60	0.66	0.79	0.99	0.66	0.73	0.87	1.00	5 - 10
Industrial	0.63	0.69	0.83	1.00	0.70	0.77	0.92	1.00	0.77	0.85	1.00	1.00	
Garden Apartments	0.54	0.59	0.71	0.89	0.60	0.66	0.79	0.99	0.66	0.73	0.87	1.00	
Churches	0.54	0.59	0.71	0.89	0.60	0.66	0.79	0.99	0.66	0.73	0.87	1.00	
Schools	0.31	0.34	0.41	0.51	0.35	0.39	0.46	0.58	0.39	0.43	0.51	0.64	10 - 15
Semi Detached Residential	0.45	0.50	0.59	0.74	0.50	0.55	0.66	0.83	0.55	0.61	0.73	0.91	
Detached Residential	0.40	0.44	0.53	0.66	0.45	0.50	0.59	0.74	0.50	0.55	0.66	0.83	
Quarter Acre Lots	0.36	0.40	0.48	0.59	0.40	0.44	0.53	0.66	0.44	0.48	0.58	0.73	
Half Acre Lots	0.31	0.34	0.41	0.51	0.35	0.39	0.46	0.58	0.39	0.43	0.51	0.64	
Parkland	0.18	0.20	0.24	0.30	0.20	0.22	0.26	0.33	0.22	0.24	0.29	0.36	To be Computed

Source: HERPICC Stormwater Drainage Manual, July 1995.

(1) Flat terrain involves slopes of 0-2%.
(2) Rolling terrain involves slopes of 2-7%.
(3) Steep terrain involves slopes greater than 7%.
(4) Interpolation, extrapolation and adjustment for local conditions shall be based on engineering experience and judgment.

B. Development Sites Greater Than 5 Acres in Size or Contributing Drainage Area Greater than 25 Acres or With Significant Depressional Storage

The runoff rate for these development sites and contributing drainage areas shall be determined by a computer model that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

LID Exception: If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 8 (Post-Construction Stormwater Quality Management Standards), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 8 and BMP fact sheets may be determined based on pre-development underlying soil layer.

The 24-hour NRCS Type 2 Rainfall Distribution shall be utilized for runoff calculations. 24-hour Rainfall depth for various frequencies shall be taken from **Table 2-5**. The NRCS Type 2 distribution ordinates are found in **Table 2-6**. Examples of computer models that can generate such hydrographs include TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE). These programs may be downloaded free of charge from the associated agencies' web sites. The computer models ICPR, Pond Pack, and HydroFlow Hydrograph may also be used. However, the latter computer software are proprietary. If interconnected ponds are utilized, the use of ICPR or Pond Pack may be required to appropriately model the more complex hydrologic and hydraulic relationships associated with such system. Other models may be acceptable and must be accepted by the City prior to their utilization.

TABLE 2-4

Rainfall Intensities for Various Return Periods and Storm Durations							
Duration	*Intensity (Inches/Hour)*						
	Return Period (Years)						
	1	2	5	10	25	50	100
5 min	5.09	6.02	7.14	8.09	9.26	10.26	11.2
10 min	3.95	4.7	5.54	6.24	7.09	7.78	8.42
15 min	3.23	3.83	4.54	5.12	5.84	6.42	6.98
30 min	2.14	2.56	3.11	3.55	4.12	4.59	5.04
1 hr	1.3	1.57	1.95	2.26	2.67	3.02	3.37
2 hr	0.76	0.92	1.15	1.34	1.6	1.82	2.05
3 hr	0.54	0.65	0.81	0.95	1.14	1.3	1.47
6 hr	0.32	0.39	0.48	0.56	0.68	0.78	0.88
12 hr	0.19	0.22	0.28	0.32	0.38	0.43	0.49
24 hr	0.11	0.13	0.16	0.18	0.21	0.23	0.26

Source: NOAA, National Weather Service, "Precipitation-Frequency Atlas of the United States", NOAA Atlas 14, Volume 2, Version 2, 2004, for Fishers, Indiana. (Partial Duration series, upper 90% Confidence Interval, values for intermediate durations can be logarithmically interpolated.)

TABEL 2-5

Rainfall Depths for Various Return Periods							
Duration	*Depth (Inches)*						
	Return Period (Years)						
	1	2	5	10	25	50	100
24 Hrs.	2.54	3.05	3.75	4.29	5.04	5.62	6.22

Source: NOAA, National Weather Service, "Precipitation-Frequency Atlas of the United States", NOAA Atlas 14, Volume 2, Version 2, 2004, for Fishers, Indiana. (Partial Duration series, upper 90% Confidence Interval).

TABLE 2-6

NRCS Type II Rainfall Distribution Ordinates					
Cumulative Storm Time (hr)	*Cumulative Percent of Storm Depth*	*Cumulative Storm Time (hr)*	*Cumulative Percent of Storm Depth*	*Cumulative Storm Time (hr)*	*Cumulative Percent of Storm Depth*
0.00	0	8.25	12.6	16.50	89.3
0.25	0.2	8.50	13.3	16.75	89.8
0.50	0.5	8.75	14	17.00	90.3
0.75	0.8	9.00	14.7	17.25	90.8
1.00	1.1	9.25	15.5	17.50	91.3
1.25	1.4	9.50	16.3	17.75	91.8
1.50	1.7	9.75	17.2	18.00	92.2
1.75	2	10.00	18.1	18.25	92.6
2.00	2.3	10.25	19.1	18.50	93
2.25	2.6	10.50	20.3	18.75	93.4
2.50	2.9	10.75	21.8	19.00	93.8
2.75	3.2	11.00	23.6	19.25	94.2
3.00	3.5	11.25	25.7	19.50	94.6
3.25	3.8	11.50	28.3	19.75	95
3.50	4.1	11.75	38.7	20.00	95.3
3.75	4.4	12.00	66.3	20.25	95.6
4.00	4.8	12.25	70.7	20.50	95.9
4.25	5.2	12.50	73.5	20.75	96.2
4.50	5.6	12.75	75.8	21.00	96.5
4.75	6	13.00	77.6	21.25	96.8
5.00	6.4	13.25	79.1	21.50	97.1
5.25	6.8	13.50	80.4	21.75	97.4
5.50	7.2	13.75	81.5	22.00	97.7
5.75	7.6	14.00	82.5	22.25	98
6.00	8	14.25	83.4	22.50	98.3
6.25	8.5	14.50	84.2	22.75	98.6
6.50	9	14.75	84.9	23.00	98.9
6.75	9.5	15.00	85.6	23.25	99.2
7.00	10	15.25	86.3	23.50	99.5
7.25	10.5	15.50	86.9	23.75	99.8
7.50	11	15.75	87.5	24.00	100
7.75	11.5	16.00	88.1		
8.00	12	16.25	88.7		

Source: National Resources Conservation Service (NRCS), "TR-20 Computer Program for Project Formulation Hydrology", page F9, May 1982.

NOTE: For use only when the SCS Type II rainfall distribution is not a default option in the computer program.

C. Development Sites with Drainage Areas Greater than or Equal to One Square Mile

For the design of any major drainage system, as defined in **Appendix A**, the discharge must be obtained from, or be accepted by, the IDNR. Other portions of the site must use the discharge methodology in the applicable section of this Article.

Chapter Three

METHODOLOGY FOR DETERMINATION OF DETENTION STORAGE VOLUMES

All runoff detention storage calculations for these development sites shall be prepared using a computer model that can generate hydrographs based on the NRCS TR-55 time of concentration and curve number calculation methodologies. Note that for the purpose of determining the post-developed conditions curve numbers, due to significant disturbance to the upper soil layers during the construction activities, the initially determined hydrologic soil group for disturbed areas should be changed to the next less infiltrating capacity category (i.e., A to B, B to C, and C to D).

LID Exception: If Low Impact Development (LID) approach is pursued in satisfying the requirements noted in Chapter 8 (Post-Construction Stormwater Quality Management Standards), the post-developed CN for the protected undisturbed or restored disturbed areas meeting the requirements described in Chapter 8 and BMP fact sheets may be determined based on pre-development underlying soil layer.

The 24-hour NRCS Type 2 Rainfall Distribution shall be utilized to determine the required storage volume. The allowable release rates shall be determined based on the methodologies provided in Chapter 6 of this Technical Standards Manual. Examples of computer models that can generate such hydrographs include TR-55 (NRCS), TR-20 (NRCS), HEC-HMS (COE), and HEC-1 (COE). These programs may be downloaded free of charge from the associated agencies' web sites. The computer models ICPR and Pond Pack may also be used. However, the latter computer software are proprietary. If interconnected ponds are utilized, the use of ICPR or Pond Pack may be required to appropriately model the more complex hydrologic and hydraulic relationships associated with such system. Other models may be acceptable and must be accepted by the City prior to their utilization.

Chapter Four

STORM SEWER DESIGN STANDARDS AND SPECIFICATIONS

All storm sewers, whether private or public, and whether constructed on private or public property shall conform to the design standards and other requirements contained herein.

A. Design Storm Frequencies

1. All storm sewers, inlets, catch basins, and street gutters shall accommodate (subject to the "allowable spread" provisions discussed later in this Section), as a minimum, peak runoff from a 10-year return frequency storm calculated based on methodology described in Chapter 2. Additional discharges to storm sewer systems allowed in Section L below of this Section must be considered in all design calculations. For Rational Method analysis, the duration shall be equal to the time of concentration for the drainage area. In computer based analysis, the duration is as noted in the applicable methodology associated with the computer program.

2. Culvert capacities for conveyance under interior local, collector, or arterial streets without roadway overtopping shall be the runoff resulting from the 25-year, 50-year, and 100-year frequency storms, respectively, for off-site areas under existing condition and on-site areas under post-developed conditions. Driveway culvert capacities shall be capacities required for the street classification to which the driveway connects. Greater culvert capacity shall be required to protect the finished floor elevation of buildings from the post-developed 100-year frequency storm when, in the opinion of the design engineer or the City, the finished floor elevation is threatened. The culvert should be sized for the 100-year frequency storm with no overtopping if it provides the only access to and from any portion of any commercial or residential developments.

3. For portions of the system considered minor drainage systems, the allowable spread of water on Collector Streets is limited to maintaining two clear 10-foot moving lanes of traffic. One lane is to be maintained on local roads, while other access lanes (such as a subdivision cul-de-sac) can have a water spread equal to one-half of their total width.

4. To ensure access to buildings and allow the use of the roadway by emergency vehicles during storms larger than the design storm, an overflow channel/swale between sag inlets and overflow paths or basin shall be provided at sag inlets so that the maximum depth of water that might be

ponded in the street sag shall not exceed 7 inches measured from elevation of gutter. All water shall be contained in the right-of-way for a 100-year storm.

5. Facilities functioning as a major drainage system as defined in **Appendix A** must also meet IDNR design standards in addition to the City of Fishers standards. In case of discrepancy, the most restrictive requirements shall apply.

6. Pipe, 12 inches or larger in diameter, shall be placed in a 30-foot easement (15 feet from centerline on each side) and shall be designated on the recorded plat as a 30-foot drainage easement. Wider easements may be required by the Director of Engineering or designee when the depth of pipe is greater than 6 to 10 feet, depending on the pipe size.

B. Manning's Equation

Determination of hydraulic capacity for storm sewers sized by the

Rational Method analysis must be done using Manning's Equation. where:

$$V = (1.486/n)(R^{2/3})(S^{1/2})$$

Then:

$$Q=(V)(A)$$

Where:

Q = capacity in cubic feet per second

V = mean velocity of flow in feet per second

A = cross sectional area in square feet

R = hydraulic radius in feet

S = slope of the energy grade line in feet per foot

n = Manning's "n" or roughness coefficient

The hydraulic radius, R, is defined as the cross sectional area of flow divided by the wetted flow surface or wetted perimeter. Allowable "n" values and full-flow maximum permissible velocities for storm sewer materials are listed in **Table 4-1**.

C. Backwater Method for Pipe System Analysis

For hydraulic analysis of existing or proposed storm drains which possess submerged outfalls, a more sophisticated design/analysis methodology than Manning's equation will be required. The backwater analysis method provides a more accurate estimate of pipe flow by calculating individual head losses in pipe systems that are surcharged and/or have submerged outlets. These head losses are added to a known downstream water surface elevation to give a design water surface elevation for a given flow at the desired upstream location. Total head losses may be determined as follows:

Total head loss = frictional loss + manhole loss + velocity head loss + junction loss

Various computer modeling programs such as HYDRA, ILLUDRAIN, and STORMCAD are available for analysis of storm drains under these conditions. Computer models to be utilized, other than those listed, must be accepted by the Director of Engineering prior to their utilization.

TABLE 4-1

Typical Values of Manning's "n"		
Material	*Manning's "n"*	*Maximum Velocities (feet/second)*
◆ **Closed Conduits**		
Concrete	0.013	10
Vitrified Clay	0.013	10
HDPE	0.012	10
PVC	0.011	10
◆ **Circular CMP, Annular Corrugations, 2 2/3 x ½ inch**		
Unpaved	0.024	7
25% Paved	0.021	7
50% Paved	0.018	7
100% Paved	0.013	7
Concrete Culverts	0.013	10
HDPE or PVC	0.012	10
◆ **Open Channels**		
Concrete, Trowel Finish	0.013	10
Concrete, Broom Finish	0.015	10
Gunite	0.018	10
Riprap Placed	0.030	10
Riprap Dumped	0.035	10
Gabion	0.028	10
New Earth **(1)**	0.025	4
Existing Earth **(2)**	0.030	4
Dense Growth of Weeds	0.040	4
Dense Weeds and Brush	0.040	4
Swale with Grass	0.035	4

Source of manning "n" values: HERPICC Stormwater Drainage Manual, July 1995.

(1) New earth (uniform, sodded, clay soil)

(2) Existing earth (fairly uniform, with some weeds).

D. Minimum Size for Storm Sewers

The minimum diameter of all storm sewers shall be 12 inches. When the minimum 12-inch diameter pipe will not limit the rate of release to the required amount, the rate of release for detention storage shall be controlled by an orifice plate or other device, subject to acceptance of the Director of Engineering.

E. Pipe Cover, Grade, and Separation from Sanitary Sewers

Pipe grade shall be such that, in general, a minimum of 2.0 feet of cover is maintained over the top of the pipe. If the pipe is to be placed under pavement, then the minimum pipe cover shall be 2.5 feet from top of pavement to top of pipe. Pipe cover less than the minimum may be allowed per manufacturer's specifications or recommendation and used only upon written acceptance from the Director of Engineering. However, the applicant must show that such smaller cover depth would still meet gross vehicle weight rating of the largest City of Fishers Fire Department truck. Uniform slopes shall be maintained between inlets, manholes and inlets to manholes. Final grade shall be set with full consideration of the capacity required, sedimentation problems, and other design parameters. Minimum and maximum allowable slopes shall be those capable of producing velocities of between 2.5 and 10 feet per second, respectively, when the sewer is flowing full. Maximum permissible velocities for various storm sewer materials are listed in **Table 4-1**. A minimum of 2.0 feet of vertical separation between storm sewers and sanitary sewers shall be required. When this is not possible, the sanitary sewer must be encased in concrete or ductile steel within 5 feet, each side, of the crossing centerline.

F. Alignment

Storm sewers shall be straight between manholes and/or inlets.

G. Manholes/Inlets

All Inlets must be sized properly and pre-stamped with an appropriate clean water message per City of Fishers Standard Construction Details. Manholes shall be provided at the following locations:

1. Where two or more storm sewers converge.
2. Where pipe size or the pipe material changes.
3. Where a change in horizontal alignment occurs.
4. Where a change in pipe slope occurs.
5. At intervals in straight sections of sewer, not to exceed the maximum allowed. The maximum distance between storm sewer manholes shall be as shown in **Table 4-2**.

TABLE 4-2

Maximum Distance Between Manholes	
Size of Pipe (Inches)	**Maximum Distance (Feet)**
All Sizes	400

Pipe slope should not be so steep that inlets surcharge (i.e. hydraulic grade line should remain below rim elevation).

6. Manhole/inlet inside sizing shall be according to the City of Fishers Standard Construction Details. Note that the downstream most structure prior to the detention basin that collects water from within the ROW shall be required to have a 2 feet deep sump. This structure must also be located within 15 feet of the curb, where practical. If this structure cannot be placed within 15 feet of the curb, at a minimum, it must be located within an easement and be easily accessible for maintenance. If the last structure does not meet this criterion, then the structure must be moved up the pipe run until this requirement is satisfied. Also, if this structure is a curb inlet and the structure sizing chart would allow this to be a 2’ x 2’ box, it must be upsized to a 48” box because of the 2’ sump.

H. Inlet Sizing and Spacing

Inlets or drainage structures shall be utilized to collect surface water through grated openings and convey it to storm sewers, channels, or culverts. The inlet grate opening provided shall be adequate to pass the design 10-year flow with 50% of the sag inlet areas clogged. An overload channel from sag inlets to the overflow channel or basin shall be provided at sag inlets. Inlet design and spacing may be done using the hydraulic equations by manufacturers or orifice/weir equations. Use of the U.S. Army Corps of Engineers HEC-12 computer program is also an acceptable method. Gutter spread on continuous grades may be determined using the Manning's equation, or by using **Figure 4-1**.

Inlet spacing shall be determined by the project engineer but shall follow the manhole spacing requirements above in Section G, Subsection 5.

Further guidance regarding gutter spread calculation may be found in the latest edition of HERPICC Stormwater Drainage Manual, available from the Local Technical Assistance Program (LTAP). At the time of printing of this document, contact information for LTAP was:

Indiana LTAP
Purdue University
Toll-Free: (800) 428-7369 (Indiana only)
Phone: (765) 494-2164
Fax: (765) 496-1176
Email: inltap@ecn.purdue.edu
Website: www.purdue.edu/INLTAP/

I. Installation and Workmanship

The point of commencement for laying a storm sewer pipe shall be the lowest point in the proposed sewer line. All pipes shall be laid, without break, upgrade from structure to structure. All storm sewer pipe outlets shall have poured in place toewalls with anchor bolts.

Bedding and backfill materials around storm sewer pipes, sub-drains, and the associated structures shall be in accordance with the City of Fishers Standard Construction Details. The specifications for the construction of storm sewers and sub-drains, including backfill requirements, shall not be less stringent than those set forth in the latest edition of the “INDOT Standard Specifications". Additionally, ductile iron pipe shall be laid in accordance with American Water Works Association (AWWA) C-600 and clay pipe shall be laid in accordance with either American Society of Testing Materials (ASTM) C-12 or the appropriate American Association of State Highway and Transportation Officials (AASHTO) specifications. Dips/sags on newly installed storm systems will not be allowed. Also, infiltration from cracks, missing pieces, and joints shall not be allowed. Variations from these standards must be justified and receive written acceptance from the Director of Engineering. All structures shall require inspection prior to backfill.

J. Materials

Storm sewer manholes and inlets shall be constructed of cast-in-place concrete or precast reinforced concrete. Material and construction shall conform to the latest edition of the Indiana Department of Transportation (INDOT) "Standard Specifications", Sections 702 and 720. Refer to the City of Fishers Standard Construction Details for additional notes.

Pipe and fittings used in storm sewer construction shall be a minimum of Class III reinforced concrete (AASHTO M170). **A higher class concrete may be required based on the design engineer’s recommendation or the Director of Engineering based on special pavement loading circumstances.** Other pipe materials such as ductile iron pipe (AWWA C-151), poly vinyl chloride pipe (AASHTO M252), high density polyethylene (HDPE), or High Performance Polypropylene (HP) may be used within commercial parking lots or private, non-paved areas.. If HDPE or PVC pipe is used in these areas, the pipe type must be converted back to concrete at the first available structure. If the first available structure is outside of the parking or non-paved area and would require the HDPE, HP, or PVC pipe to extend beneath a private street or into City ROW, an additional structure must be provided within the parking or non-paved area to convert the pipe back to concrete before crossing a street or City ROW. If HDPE pipe is used, the pipe must be mandrel tested 45 days after installation with a City inspector on site. If deflection within the pipe exceeds 5% of the inside diameter, replacement will be required. Other pipe and fittings not specified herein may be used only when specifically authorized by the Director of Engineering. Pipe joints shall be flexible and watertight and shall conform to the requirements of Section 906, of the latest edition of the INDOT "Standard Specifications".

K. Special Hydraulic Structures

Special hydraulic structures required to control the flow of water in storm runoff drainage systems include junction chambers, drop manholes, stilling basins, and other special structures. The use of these structures shall be limited to those locations justified by prudent planning and by careful and thorough hydraulic engineering analysis. Certification of special structures by a certified Structural Engineer may also be required.

The use of stormwater lift stations are not allowed within the City of Fishers.

L. Connections to Storm Sewer System

To allow any connections to the storm sewer system, provisions for the connections shall be shown in the drainage calculations for the system. Specific language shall be provided in the protective covenants, on the record plat, or with the parcel deed of record, noting the ability or inability of the system to accommodate any permitted connections, for example, sump pumps and footing drains.

1. **Sump pumps** installed to receive and discharge groundwater or other stormwater shall be connected to underdrains or storm sewers beneath designated storm drainage channels/swales within the rear or side yard drainage easement when available. Sumps are not allowed to be connected to the curb underdrain. Grinder pumps installed to receive and discharge floor drain flow or other sanitary sewage shall be connected to the sanitary sewers. A sump pump shall only be used for the discharge of stormwater or footing and perimeter drain groundwater. For existing construction where no underdrain is available or where an existing underdrain has failed, sump pumps may daylight to swales, channels, ponds, or other waterways

and/or to designated rear yard drainage easements within the property boundaries of the sump source. Sump pumps are not permitted to be discharged across sidewalks or within the right-of-way without authorization from the City Director of Public Works.

2. **Footing drains and perimeter drains** shall be connected to sump pumps and discharged into underdrains beneath designated storm drainage channels/swales. If sufficient grade is available between the footing and/or perimeter drain location and the swale to allow for a positive gravity outlet, it is required that this method be used to prevent overuse and burnout of sump pumps.

3. All **roof downspouts**, roof drains, or roof drainage piping shall discharge onto the ground and shall not be directly connected to the storm drainage system, directed toward the street, or across a sidewalk. No downspouts or roof drains shall be connected to the sanitary sewers.

4. **Garage and Basement floor drains** shall not be connected to the storm sewers. These drains shall be daylighted onto the lawn away from direct stormwater conveyance channels or connected to the sanitary sewer system where allowed.

5. **Swimming Pool drains** shall not be connected to the storm sewers or discharged to swales unless the water is dechlorinated, as defined in Appendix A, prior to being connected to the storm sewer. Swimming pool discharge water shall be directed to the sanitary sewer system when possible or to open lawn areas away from stormwater conveyance channels. When possible the water should be dechlorinated prior to discharge to a lawn area.

6. Storm Sewer Connection Requirements:

   a. Call utility locates to determine the storm sewer locations.
   b. Carefully excavate down to the storm sewer depth or the required depth for a structure tap.
   c. Core drill a hole size slightly larger than the diameter of the drain tile or sump line connection diameter.
   d. Drain tile connection must be flush with the inside wall of the pipe or structure.
   e. Grout the drain tile or sump pump pipe to the storm pipe or structure wall with a cement-based hydraulic cement.
   f. Backfill around the drain tile or sump pump pipe and the storm pipe or structure with #8 stone. If the excavation is within the road right-of-way, use flowable fill per the right-of-way excavation permit requirements.

g. Backfill any remaining excavation volume with the original soils and compact the excavation with a vibratory or similar compactor.
h. Use seed and straw or seed and erosion control blanket (if within a swale flowline) to restore the disturbed area of the excavation area.

In addition, none of the above mentioned devices shall be connected to any street underdrains, unless specifically authorized by the Director of Public Works.

M. Drainage System Overflow Design

Overflow path/ponding areas throughout the development to the pond resulting from a 100-year storm event, calculated based on all contributing drainage areas, on-site and off-site, in their proposed or reasonably anticipated land use and with storm pipe system assumed completely plugged, shall be determined. This overflow path shall be clearly shown as a distinctive hatch pattern on the plans, and a 30-foot swath along the centerline of the overflow path must be designated as permanent drainage easement. The overflow path hatch pattern shall be bordered by the proposed topographic elevation that this water surface elevation would match under this overflow condition. A continuous flood route from the sag inlets to the final outfall shall be shown and the minimum 30-feet along the centerline contained within an easement or road right-of-way regardless of the 100-year storm event ponding elevation. There shall be no trees or shrubs planted, nor any structures or fences erected within the easement areas. These areas are easements that are to be maintained by the property owners or be designated as common areas to be maintained by the homeowners association. The minimum adjacent grade of the portion of any residential, commercial, or industrial building (the ground elevation next to the building after construction is completed) that sits adjacent to the emergency flood route or may be subject to flooding by the emergency flood route shall be a minimum of 1 foot above the estimated 100-year elevation of the emergency flood route assuming that all stormwater pipes are fully clogged.

The required minimum adjacent grade of buildings adjacent to an overflow path is provided in **Table 4-3**.

TABLE 4-3

Minimum Building Adjacent Grade With Respect to Overflow Path Invert Elevations		
Drainage Area (Acres)	**Minimum Building Adjacent Grade Above Overflow Path Invert (Feet)[1]**	**Minimum Building Adjacent Grade Above Overflow Path Invert, if Overflow Path is in the Street (Feet)[1]**
Up to 5	2.50	1.50

6-10	3.00	1.50
11-15	3.25	1.75
16-20	3.50	1.75
21-30	4.00	2.00
30-50	4.25	2.00

Notes: [1] The overflow path Invert refers to the elevation of the flow line of the emergency flow route (typically in the form of a channel, swale, or gutter) nearest to the upstream end of a building

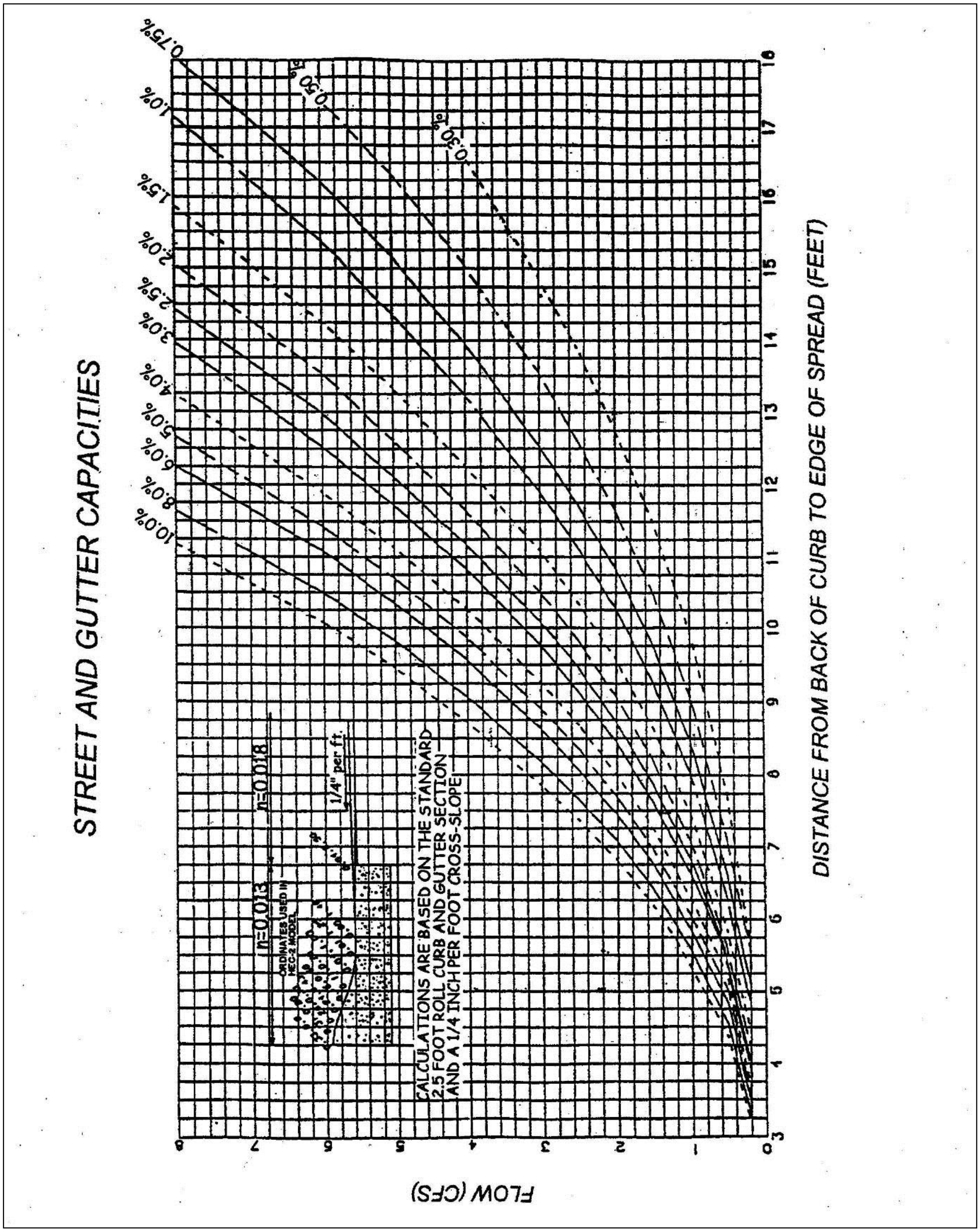
As an alternative to using default values in Table 4-3, the overflow path/ponding may be modeled as successive series of natural ponds and open channel segments. Ponds should be modeled similar to that discussed for modeling depressional areas in Chapter 6. Channels should be modeled according to modeling techniques discussed in Chapter 5. The calculations for determining the 100-year overflow path/ponding elevations may be based on hand calculation methods utilizing normal depth calculations and storage routing techniques or performed by computer models. Examples of computer models that either individually or in combination with other models can handle the required computations include TR-20, HEC-HMS, and HEC-1, combined with HEC-RAS. Other models may be acceptable and should be accepted by the City prior to their utilization.

Simply using the values in Table 4-3 is preferred over the much more complicated detailed modeling of the overflow/ponding areas. However, regardless of the methodology used, the City reserves the right to require independent calculations to verify that the proposed building minimum adjacent grade facing the flood route or the portion of building having a potential to be subject to flooding by the flood route provide adequate freeboard above the anticipated overflow path/ponding elevations.

The LAG requirements for buildings adjacent to other flooding sources are discussed elsewhere in the Resolution or in this Manual. In case there are more than one flooding sources applicable to a building site, the highest calculated LAG for the building shall govern the placement of the building on that site

In the case of existing upstream detention, an allowance equivalent to the reduction in flow rate provided may be made for upstream detention only when: (1) such detention and release rate have previously been accepted by the Director of Engineering or the City official charged with the approval authority at the time of the acceptance, and (2) evidence of its construction and maintenance can be shown.

FIGURE 4-1
Street and Gutter Capacities (continuous grade)



Chapter Five

OPEN CHANNEL DESIGN STANDARDS AND SPECIFICATIONS

All channels, whether private or public, and whether constructed on private or public land, shall conform to the design standards and other design requirements contained herein.

A. Design Storm Frequencies

1. All channels and swales shall accommodate, as a minimum, peak runoff from a 24-hour, 10-year return frequency storm calculated based on methodology described in Chapter 2. For Rational Method analysis, the storm duration shall be equal to the time of concentration for the drainage area. In computer-based analysis, the duration is as noted in the applicable methodology associated with the computer program.

2. Channels with a carrying capacity of more than 30 cfs at bank-full stage shall be capable of accommodating peak runoff for a 24-hour, 50-year return frequency storm within the drainage easement.

3. Channel facilities functioning as a major drainage system, as defined in **Appendix A**, must also meet IDNR design standards in addition to the City of Fishers standards. However, channel facilities with a contributing drainage area of less than 1 square mile and more than 25 acres do not have to model the floodway if construction is not allowed within that floodway. In addition, simpler methods such as cross section analysis may be utilized and existing upstream detention may be considered within the modeling.

4. The 10-year storm design flow for residential rear and side lot swales shall not exceed 4 cfs. Unless designed as the sole Post-construction stormwater quality BMP, the maximum length of rear and side lot swales before reaching any inlet shall not exceed 300 feet. A rear or side yard swale shall be defined as the distance between a high point and an inlet.

5. Regardless of minimum design frequencies stated above, the performance of all parts of drainage system shall be checked for the 100-year flow conditions to ensure that all buildings are properly located outside the 100-year flood boundary and that flow paths are confined to designated areas with sufficient easement.

B. Manning's Equation

The waterway area for channels shall be determined using Manning's Equation, where:

$$A = Q/V$$

A = Waterway area of channel in square feet

Q = Discharge in cubic feet per second (cfs)

V = Steady-State channel velocity, as defined by Manning's Equation (See Chapter 4)

C. Backwater Method for Drainage System Analysis

The determination of 100-year water surface elevation along channels and swales shall be based on accepted methodology and computer programs designed for this purpose. Computer programs HEC-RAS, HEC-2, and ICPR are preferred programs for conducting such backwater analysis. The use of other computer models must be accepted in advance by the Director of Engineering.

D. Channel Cross-Section and Grade

1. The required channel cross-section and grade are determined by the design capacity, the material in which the channel is to be constructed, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains, tributary ditches, or streams. The channel grade shall be such that the velocity in the channel is high enough to prevent siltation but low enough to prevent erosion. Velocities less than 2 feet per second (fps) are not acceptable, as siltation will take place and ultimately reduce the channel cross-section area. The maximum permissible velocities in vegetated-lined channels are shown in **Table 5-1.** In addition to existing runoff, the channel design should incorporate increased runoff due to the proposed development.

2. Where depth of design flow is slightly below critical depth, channels shall have freeboard adequate to cope with the effect of hydraulic jumps.

3. Along the streets and roads, the bottom of the ditch should be low enough to install adequately-sized driveway culverts without creating "speed

bumps". The driveway culvert inverts shall be designed to adequately consider upstream and downstream culvert elevations.

4. Flow of a channel into a closed system is prohibited, unless runoff rate and head loss computations demonstrate the closed conduit to be capable of carrying the 100-year channel flow for developed conditions, either entirely or in combination with a defined overflow channel, with no reduction of velocity.

TABLE 5-1

Maximum Permissible Velocities in Vegetal-Lined Channels (1)			
Cover	*Channel Slope Range (Percent)* **(3)**	*Permissible Velocity* **(2)**	
		Erosion Resistant Soils (ft. per sec.) **(4)**	*Easily Eroded Soils (ft. per sec.)* **(4)**
Bermuda Grass	0-5 5-10 Over 10	8 7 6	6 5 4
Bahia Buffalo Grass Kentucky Bluegrass Smooth Brome Blue Grama	0-5 5-10 Over 10	7 6 5	5 4 3
Grass Mixture Reed Canary Grass	**(3)** 0-5 5-10	5 4	4 3
Lespedeza Sericea Weeping Lovegrass Yellow Bluestem Redtop Alfalfa Red Fescue	**(4)** 0-5 5-10	3.4	2.5
Common Lespedeza **(5)** Sudangrass **(5)**	**(6)** 0-5	3.5	2.5

(1) From Soil Conservation Service, SCS-TP-61, "Handbook of Channel Design for Soil and Water Conservation".
(2) Use velocities exceeding 5 feet per second only where good channel ground covers and proper maintenance can be obtained.
(3) Do not use on slopes steeper than 10 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.
(4) Do not use on slopes steeper than 5 percent except for vegetated side slopes in combination with a stone, concrete, or highly resistant vegetative center section.
(5) Annuals - use on mild slopes or as temporary protection until permanent covers are established.
(6) Use on slopes steeper than 5 percent is not recommended.

E. Side Slopes

1. Earthen channel and swale side slopes shall be no steeper than 3 horizontal to 1 vertical (3:1). Flatter slopes may be required to prevent erosion and for ease of maintenance.

2. Where channels will be lined with riprap, concrete, or other acceptable lining method, side slopes shall be no steeper than 2 horizontal to 1 vertical (2:1) with adequate provisions made for weep holes.

3. Side slopes steeper than 2 horizontal to 1 vertical (2:1) may be used for lined channels provided that the side lining is designed and constructed as a structural retaining wall with provisions for live and dead load surcharge.

4. When the design discharge produces a depth of greater than three (3) feet in the channel, appropriate safety precautions shall be added to the design criteria based on reasonably anticipated safety needs.

5. The lowest adjacent grade of commercial, industrial, institutional, municipal, and residential buildings shall be placed two (2) feet above the 100 year flood elevation of the channel or swale.

F. Channel Stability

1. Characteristics of a stable channel are:

   a] It neither promotes sedimentation nor degrades the channel bottom and sides.

   b] The channel banks do not erode to the extent that the channel cross-section is changed appreciably.

   c] Excessive sediment bars do not develop.

   d] Excessive erosion does not occur around culverts, bridges, outfalls or elsewhere.

   e] Gullies do not form or enlarge due to the entry of uncontrolled flow to the channel.

2. Channel stability shall be determined for an aged condition and the velocity shall be based on the design flow or the bankfull flow, whichever is greater, using an "n" value for various channel linings as shown in **Tables 4-1 and**

5-1. In no case is it necessary to check channel stability for discharges greater than that from a 100-year frequency storm.

3. Channel stability shall be checked for conditions representing the period immediately after construction. For this stability analysis, the velocity shall be calculated for the expected flow from a 10-year frequency storm on the watershed, or the bankfull flow, whichever is smaller, and the "n" value for the newly constructed channels in fine-grained soils and sands may be determined in accordance with the "National Engineering Handbook 5, Supplement B, Soil Conservation Service" and shall not exceed 0.025. This reference may be obtained by contacting the National Technical Information Service in Springfield. The allowable velocity in the newly constructed channel may be increased by a maximum of 20 percent to reflect the effects of vegetation to be established under the following conditions:

   a] The soil and site in which the channel is to be constructed are suitable for rapid establishment and support of erosion controlling vegetation.

   b] Species of erosion controlling vegetation adapted to the area, and proven methods of establishment are shown.

   c] The channel design includes detailed plans for establishment of vegetation on the channel side slopes.

G. Drainage of Swales

Swale slopes should be 1.0%, if practical, with a minimum slope of 0.5% with underdrain required unless designed to act as a Post-construction stormwater quality BMP. All flow shall be confined to the specific drainage easements associated with each rear and side lot swale that are part of the minor drainage system. Unless designed to act as a stormwater quality BMP, vegetated swales shall have tile underdrains to dry the swales in accordance with the City of Fishers Standard Construction Details. Tile lines may be connected to a drop structure at the ends of the swale or through a standard tile outlet. Further guidance regarding this subject may be found in the latest edition of the Indiana Drainage Handbook or the Indiana Stormwater Quality Manual.

H. Appurtenant Structures

The design of channels will include provisions for operation and maintenance and the proper functioning of all channels, laterals, travelways, and structures associated with the project. Recessed inlets and structures needed for entry of surface and subsurface flow into channels without significant erosion or degradation shall be included in the design of channel improvements. The design will also provide for necessary floodgates, water level control devices, and any other appurtenance structure affecting the functioning of the channels and the attainment of the purpose for which they are built.

The effects of channel improvements on existing culverts, bridges, buried cables, pipelines, and inlet structures for surface and subsurface drainage on the channel being improved and laterals thereto shall be evaluated to determine the need for modification or replacement. Culverts and bridges which are modified or added as part of channel improvement projects shall meet reasonable standards for the type of structure, and shall have a minimum capacity equal to the design discharge or governmental agency design requirements, whichever is greater.

I. Deposition of Spoil

Spoil material resulting from clearing, grubbing, and channel excavation shall be disposed of in a manner that will:

1. Minimize overbank wash.

2. Provide for the free flow of water between the channel and floodplain boundary unless the valley routing and water surface profiles are based on continuous dikes being installed.

3. Not hinder the development of travelways for maintenance.

4. Leave the right-of-way in the best condition feasible, consistent with the project purposes, for productive use by the owner.

5. Be accepted by the IDNR or COE, if applicable.

J. Materials

Materials acceptable for use as channel lining are:

1. Grass (hand sown or hydroseed)
2. Revetment Riprap
3. Concrete
4. Hand Laid Riprap
5. Precast Cement Concrete Riprap
6. Gabions (or reno mattresses)
7. Straw Matting, Coconut Matting, or erosion control blanket (only until grass is established)

8. Channels that are creeks, rivers, or other waters of the state that are impacted by a development should use channel linings appropriate and permitted by IDEM, COE, or the IDNR and/or other appropriate state or federal agencies.

Other lining materials must be accepted in writing by the Director of Engineering. Materials shall comply with the latest edition of the INDOT, "Standard Specifications".

K. Drainage System Overflow Design

See Chapter 4, Section M.

Chapter Six

STORMWATER DETENTION DESIGN STANDARDS FOR PEAK FLOW CONTROL

The following shall govern the design of any improvement with respect to the detention of stormwater runoff. Basins shall be constructed to temporarily detain the stormwater runoff that exceeds the maximum peak release rate authorized by the Resolution. The required volume of storage provided in these basins, together with such storage as may be authorized in other on-site facilities, shall be sufficient to control excess runoff from the 10-year or 100-year storm as explained below in Section "B." Also, basins shall be constructed to provide adequate capacity to allow for sediment accumulation resulting from development and to permit the pond to function for reasonable periods between cleanings.

In addition to the requirement for peak flow control through detention, the Stormwater Management Resolution and Technical Standards require the developer to address the Water Quality requirements discussed in Chapter 8. To take advantage of optional runoff reduction incentives provided in Chapter 8, which can reduce the required detention storage size for peak flow control, the proper way to accommodate the water quality, channel protection (if provided), and peak flow rate control of a site is to first consider addressing the water quality (and the optional channel protection volume, if provided) requirements through conventional or LID approaches (as described in Chapter 8) and then determine the size and dimensions of the required detention storage for peak flow rate control. Chapter 8 provides several BMPs and options to address the water quality requirements. However, in many cases, providing some level of extended detention may become necessary to meet those requirements. While such extended detention is best provided in a separate facility, many developers choose to combine the needed extended detention feature with the detention pond needed for peak runoff rate control of the site into one facility.

Due to varying needed detention times, combining the extended detention with the regular peak flow detention facility could pose design challenges. The following is the suggested calculation sequence for designing a detention pond for peak flow control either as a single-purpose facility or when combined with extended detention .

<u>Peak Flow Control Facility (single use)</u>

1. Determine the control elevation/invert for the outlet serving the proposed peak flow control detention storage (ensuring a positive drain to the site outlet). This will be the elevation of the bottom of the proposed peak flow control storage and top of the permanent pool if a wet bottom pond is being provided.

2. Design the main outlet of the peak flow rate control detention storage, sized to carry the allowable on-site 10-year and 100-year release rates, with its control elevation/invert at the top of the permanent pool. For storage space calculation purposes, use the actual orifice

size calculated to accommodate the release rates regardless of whether the orifice size is smaller or larger than the minimum orifice size allowed under the Stormwater Management Resolution or Technical Standards.

3. Design the peak flow rate control detention storage space by routing the on-site 10-year and 100-year inflow hydrographs through the pond, assuming the pond is empty to the control elevation of the peak flow control detention storage outlet as determined in Step 1. The resulting maximum water surface elevation is where the invert of the emergency overflow weir (sized for 1.25 times the peak inflow rate) is located. The pond size and control elevation/invert elevations are final at this stage.

4. Reroute the on-site and off-site 10-year and 100-year inflow hydrographs through the pond. The resulting maximum water surface elevation is the 100-year pool elevation.

5. If the calculated orifice size of the main peak flow rate control storage outlet is less than the minimum orifice size allowed in the Resolution or these Technical Standards, designate the minimum orifice size on the construction plans, but do not go back and recalculate/redesign the storage spaces.

Combined Peak Flow Control and Water Quality Extended Detention Facility

1. Calculate the required extended detention storage volume as needed to address the requirements noted in Chapter 8 (depending on the approach utilized, there may be no need for providing an extended detention storage).

2. Determine the control elevation/invert for the drain serving the proposed extended detention storage (ensuring a positive drain to the site outlet). This will be the elevation of the bottom of the proposed extended detention storage and top of the permanent pool if a wet bottom pond is being provided.

3. Design a storage space to accommodate the extended detention storage volume determined in Step 1, assuming 0.0 cfs going through the drain that will serve this extended detention storage volume. The top of this storage space will be the bottom of the peak flow rate control detention storage and the invert of the main outlet of this peak flow rate control detention storage.

4. Design the main outlet of the peak flow rate control detention storage, sized to carry the allowable on-site 10-year and 100-year release rates, with its control elevation/invert at the top of the extended detention storage space. For storage space calculation purposes, use the actual orifice size calculated to accommodate the release rates regardless of whether the orifice size is smaller or larger than the minimum orifice size allowed under the Stormwater Management Resolution or Technical Standards.

5. Design the peak flow rate control detention storage space by routing the on-site 10-year and 100-year inflow hydrographs through the pond, assuming the pond is empty to the control elevation of the extended detention storage drain as determined in Step 2, but still

assuming 0.0 cfs can get out of the extended detention storage drain as the pond fills up. The resulting maximum water surface elevation is where the invert of the emergency overflow weir (sized for 1.25 times the peak inflow rate) is located. The pond size and control elevation/invert elevations are final at this stage.

6. Determine the size of the extended detention storage drain and design the drain system in a manner to meet the extended detention minimum and maximum emptying time requirements discussed in Chapter 8, using both on-site and, if applicable, off-site runoff. Due to typically required clog-free design and maintenance of the extended detention storage drain structures, a smaller orifice than the minimum orifice size requirement for the main outlet may be allowed. See the Detention Basin Outlet Control Structure details on the Standard Construction Details sheets in Appendix B of the Construction Specifications Document.

7. To make sure that the addition of the release through the drain will not cause the allowable release rate to be exceeded, reroute the on-site and off-site 10-year and 100-year inflow hydrographs through the pond, this time allowing water to also leave through the extended detention storage drain as the pond fills up. If the total peak outflow discharge exceeds the allowable release rate, reduce the size of the main outlet orifice accordingly (but do not go back to redesign the storage space). The resulting maximum water surface elevation is the 100-year pool elevation.

8. If the calculated orifice size of the main peak flow rate control storage outlet is less than the minimum orifice size allowed in the Resolution or these Technical Standards, designate the minimum orifice size on the construction plans, but do not go back and recalculate/redesign the storage spaces.

Note that, in some instances such as relatively small development sites (say, less than 5 acres) or sites with highly restrictive site-specific maximum allowable release rates, when the required outlet orifice size and/or the required size of the extended detention drain will be small, the calculated drain time may extend beyond the maximum required 48-hour emptying time. Often times, the situation can be addressed through enlarging the pond volume or reconfiguring the pond's shape. When the situation cannot be resolved in a reasonable manner despite those attempts, the City may, on a case by case basis, allow deviation from the required orifice size, maximum allowable release, or emptying time after considering reasonable options and examining the potential impacts on downstream or upstream areas.

The following shall govern the design of any improvement with respect to the detention of stormwater runoff for peak flow control.

A. Acceptable Detention Facilities

The increased stormwater runoff resulting from a proposed development must be detained on-site by the provisions of appropriate wet bottom or dry bottom detention facilities, Low Impact Development (LID) techniques as described in Chapter 8, or other acceptable techniques. Measures that retard the rate of overland flow and the velocity in runoff channels shall also be used to partially control runoff rates.

B. Allowable Release Rates

1. General Release Rates

   Control devices shall limit the discharge to a rate such that the post-developed release rate from the site is no greater than 0.1 cfs per acre of development for 0-10 year return interval storms and 0.3 cfs per acre of developed area for 11 - 100 year return interval storms.

   The above fixed general release rates may be set at a lower value by the City Director of Engineering for certain watersheds if more detailed data becomes available as a result of comprehensive watershed studies conducted and/or formally approved and adopted by Fishers. The applicant shall confirm the applicable release rates with the City Director of Engineering prior to initiating the design calculations to determine whether a basin-specific rate has been established for the watershed.

   For sites where the pre-developed area has more than one (1) outlet, the release rate must be computed based on pre-developed discharge to each outlet point. The computed release rate for each outlet point shall not be exceeded at the respective outlet point even if the post developed conditions would involve a different arrangement of outlet points.

2. Site-Specific Release Rates for Sites with Depressional Storage

   For sites where depressional storage exists, the general release rates provided above may have to be further reduced. If depressional storage exists at the site, site-specific release rates must be calculated according to methodology described in Chapter 2, accounting for the depressional storage by modeling it as a pond whose outlet is a weir at an elevation that stormwater can currently overflow the depressional storage area. Post developed release rate for sites with depressional storage shall be the 2-year pre-developed peak runoff rate for the post-developed 10-year storm and 10-year pre-developed peak runoff rate for the post-developed 100-year storm. In no case shall the calculated site-specific release rates be larger than general release rates provided above.

   Note that by definition, the depressional storage does not have a direct gravity outlet but if in agricultural production, it is more than likely drained by a tile and should be modeled as "empty" at the beginning of a storm. The function of any existing depressional storage should be modeled using an event hydrograph model to determine the volume of storage that exists and its effect on the existing site release rate. To prepare such a model, certain information must be obtained, including delineating the tributary drainage area, the stage-storage relationship and discharge-rating curve, and identifying the capacity and elevation of the outlet(s).

The tributary area should be delineated on the best available topographic data. After determining the tributary area, a hydrologic analysis of the watershed should be performed, including, but not limited to, a calculation of the appropriate composite runoff curve number and time of concentration. Stage-storage data for the depressional area should be obtained from the site topography. The outlet must be clearly marked and any calculations performed to create a stage-discharge rating curve must be included with the stormwater submittal.

Also note that for determining the post-developed peak runoff rates, the depressional storage must be assumed to be filled unless the City Director of Engineering can be assured, through a dedicated easement, that the noted storage will be preserved in perpetuity.

3. Management of Off-site Runoff

Runoff from all upstream tributary areas (off-site land areas) may be bypassed around the detention/retention facility without attenuation. Such runoff may also be routed through the detention/retention facility, provided that a separate secondary outlet system is incorporated for the safe passage of such flows, i.e., not through the primary outlet of a detention facility. Unless the pond is being designed as a regional detention facility and therefore all off-site runoff to the pond detained, the primary outlet structure shall be sized and the invert elevation of the secondary outlet for bypassing off-site runoff determined according to the on-site runoff only. To accomplish this, the 100-year on-site runoff must be determined by temporarily ignoring the off-site runoff and routed through the pond and through the primary outlet pipe. The resulting pond elevation would be the invert elevation of the secondary outlet. Once the size and location of primary outlet structure and the invert elevation of the secondary outlet for bypassing off-site runoff are determined by considering on-site runoff only, the size of the secondary outlet and the 100-year pond elevation is determined by routing the entire inflow, on-site and off-site, through the pond. Once the 100-year pond elevation is determined in this manner, the crest elevation of the open emergency weir is set at that elevation.

Note that the efficiency of the detention/retention facility in controlling the on-site runoff may be severely affected if the off-site area is considerably larger than the on-site area. As a general guidance, on-line detention may not be effective in controlling on-site runoff where the ratio of off-site area to on-site area is larger than 5:1. Additional detention (above and beyond that required for on-site area) may be required by the City Director of Engineering when the ratio of off-site area to on-site area is larger than 5:1.

4. Downstream Restrictions

In the event the downstream receiving channel or storm sewer system is inadequate to accommodate the post-developed release rate provided above, then the allowable release rate shall be reduced to that rate permitted by the capacity of the receiving downstream channel or storm sewer system. Additional detention, as determined by the Director of Engineering, shall be required to store that portion of the runoff exceeding the capacity of the receiving sewers or waterways. When such downstream restrictions are suspected, the Director of Engineering may require additional analysis to determine the receiving system's limiting downstream capacity.

If the proposed development makes up only a portion of the undeveloped watershed upstream of the limiting restriction, the allowable release rate for the development shall be in direct proportion to the ratio of its drainage area to the drainage area of the entire watershed upstream of the restriction.

As an alternative to reduction of release rates, the City Director of Engineering may allow the applicant to pursue alleviating downstream restrictions. The applicant would be responsible for obtaining all permits and consents required and for incurring all expenses involved in such undertaking.

5. Documentation of Results

The results of the allowable release rate determinations as well as the modeling simulation results must be summarized in a table that shall be included in the Stormwater Drainage Technical Report and on the Drainage Plan. The table must include, for each eventual site outlet, the pre-developed acreage tributary to each eventual site outlet, the unit discharge allowable release rate used, the resulting allowable release rate in cfs for the post-developed 10-year and 100-year events, as well as pre- and post-developed flow rates for 2-, 10- and 100-year events. The worksheet provided as **Table 6-1** should be filled for each final site outlet.

TABLE 6-1

SITE OUTLET #	ITEM	PRE-DEVELOPMENT					POST-DEVELOPMENT				
		D.A. (ac)	Depress. Storage? (yes/no)	2-Yr.	10-Yr.	100-Yr.	D.A. (ac)	Depress. Storage? (yes/no)	2-Yr.	10-Yr.	100-Yr.
1	Default Unit Discharge Allowable Release Rate (cfs/acre)									0.1	0.3
	Basin-Specific Unit Discharge Allowable Release Rate, if any (cfs/acre)										
	Unit Discharge Allowable Release Rate Based on D/S Restrictions, if any (cfs/acre)										
	Adopted Unit Discharge Allowable Release Rate (cfs/acre)										
	Contributing Area of Development Site (ac) and Allowable Release Rate (cfs)										
	Total Contributing DA (ac) and Modeling Results (cfs)							no			

C. General Detention Basin Design Requirements

1. The detention facility shall be designed in such a manner that a minimum of 90% of the maximum volume of water stored and subsequently released at the design release rate shall not result in a storage duration in excess of 48 hours from the start of the storm unless additional storms occur within the period. In other words, the design shall ensure that a minimum 90% of the original detention capacity is restored within 48 hours from the start of the design 100-year storm.

2. The 100-year elevation or defined top of bank of stormwater detention facilities if the 100-year elevation is lower than the top of bank shall be separated by not less than 30 feet from any building or structure to be occupied. The Lowest Adjacent Grade (including walkout basement floor elevation) for all residential, commercial, or industrial buildings shall be set a minimum of 2 feet above the 100-year pond elevation or 2 feet above the emergency overflow weir elevation, whichever is higher. In addition to the Lowest Adjacent Grade requirements, it is recommended that any basement floor must be at least one (1) foot above the normal pool water level of any wet-bottom pond or the local seasonal high groundwater table, whichever is higher, to avoid the overuse of sump pumps and frequent flooding of the basement.

3. No detention facility or other water storage area, permanent or temporary, shall be constructed under or within twenty (20) feet of any pole or high voltage electric line. Likewise, poles or high voltage electric lines shall not be placed within twenty (20) feet of any detention facility or other water storage area.

4. There shall be a minimum of 50 feet distance between the top of the bank of stormwater detention facilities and edge of pavement of parking lots unless guard rails, berms, or other structural measures are provided to minimize the chances of vehicles sliding into the pond. Detention facilities shall be more than 150 feet away from a roadway unless structural measures, such as guard rails or berms, or other physical barriers capable of preventing the passage of a vehicle are provided. The minimum separation of all stormwater detention facilities shall be separated from roadways shall be according to **Table 6-2**, regardless of the presence of a structural or physical barrier.

TABLE 6-2

Functional Classification of Roadway	Minimum Detention Pond Setback
Principal Arterial Minor Arterial Rural Major Collector Rural Minor Collector Urban Collector Local	50 feet from Right-of-Way to the top of bank or 50 feet from Right-of-Way to maximum 100-year pool, whichever is greater.
Private Roadways	80 feet from centerline of roadway to top of bank or 80 feet from centerline of roadway to maximum 100-year pool, whichever is greater

5. Slopes no steeper than 3 horizontal to 1 vertical (3:1) for safety, erosion control, stability, and ease of maintenance shall be permitted.

6. A galvanized debris guard having a maximum opening of four (4) inches or designed in accordance to any applicable City of Fishers Standard Construction Details shall be provided for all outlets from ponds. Storm drain pipes that outlet into the pond shall not be submerged.

7. Outlet control structures shall be designed to operate as simply as possible and shall require little or no maintenance and/or attention for proper operation. For maintenance purposes, the outlet from the pond shall be a minimum of 0.5 foot above the normal water level of the receiving water body. They shall limit discharges into existing or planned downstream channels or conduits so as not to exceed the predetermined maximum authorized peak flow rate. For above ground facilities, if an outlet control structure includes an orifice to restrict the flow rate, such orifice shall be no less than six (6) inches in diameter, even if the six (6) inch diameter orifice results in a discharge that exceeds the predetermined maximum authorized peak flow release rates. However, note that the sizing of the pond must still be based on the more restrictive maximum allowable release rate.

8. Emergency overflow facilities such as a weir or spillway shall be provided for the release of exceptional storm runoff or in emergency conditions should the normal discharge devices become totally or partially inoperative. The overflow facility shall be of such design that its operation is automatic and does not require manual attention.

Emergency overflow facilities shall be designed to handle one and one-quarter (1.25) times the peak discharge and peak flow velocity resulting from the 100-year design storm event runoff from the entire contributing watershed draining to the detention/retention facility (pond total peak 100-year inflow), assuming post-development condition on-site and existing condition off-site. The length of the weir is to be determined using the weir equation, with the overflow weir control elevation at the pond's 100-year elevation (pond is assumed full to the overflow weir control elevation), discharge equal to 1.25 times the peak 100-year inflow, and the maximum head being the difference between the weir control elevation and the top of the bank.

The emergency overflow routing from the **emergency overflow facility to an adequate receiving system** must be positive (by gravity) and shown on the construction plans and on the secondary plat as a distinctive hatch pattern on a separate "Detention Emergency Overflow" sheet. The overflow path hatch pattern shall be bordered by the proposed topographic elevation that this water surface elevation would match under this overflow condition. It must be sized to accommodate the design flow of the pond's emergency overflow weir. Thirty (30) feet along the centerline of this emergency overflow route shall be designated as permanent drainage easement. No fences or landscaping can be constructed within the easement areas that may impede the free flow of stormwater. The Lowest Adjacent Grade of all residential, commercial, or industrial buildings along this emergency overflow route shall be set a minimum of 2 feet above the flood elevation along the route, calculated based on the pond's emergency overflow weir design discharge.

9. Grass or other suitable vegetative cover shall be provided along the banks of the detention storage basin. Vegetative cover around detention facilities must be maintained as appropriate. If native vegetation is planted, signage must be provided indicating that it is a natural "Do Not Mow" area. The City will not be responsible for maintenance of the detention pond and bank slopes. Trees or other woody vegetation shall be trimmed, cut and removed from pond banks.

10. Debris and trash removal and other necessary maintenance shall be performed on a regular basis to assure continued operation in conformance to design. Fishers will not be responsible for pond maintenance.

11. No residential lots, or any part thereof, shall be used for any part of a detention basin, assumed full to the 100-year water surface elevation. Detention basins, assumed full to the 100-year water surface elevation, shall be placed within a common area either platted or legally described and recorded as a perpetual drainage easement. A minimum of thirty (30) feet

of dedicated permanent drainage easement is required horizontally from the top of bank of the detention facility, or the 100-year pool if no defined top of bank is present. This thirty feet easement can be divided up between common area and/or a residential home lot as long as no part of the detention basin (defined as top of bank or the 100 year pond elevation contour) encroaches onto the residential lot per the instructions above and as long as the easement on the common area side is at least 15 feet.

12. Bank erosion occurring from including but not limited to sump pump discharges, animal burrowing, pond wave action, sheet flows, etc. shall be prevented and corrected by the pond property owner.

D. Additional Requirements for Wet-Bottom Facility Design

Where part of a detention facility will contain a permanent pool of water, all the items required for detention storage shall apply. Also, a controlled positive outlet will be required to maintain the design water level in the wet bottom facility and provide required detention storage above the design water level. However, the following additional conditions shall apply:

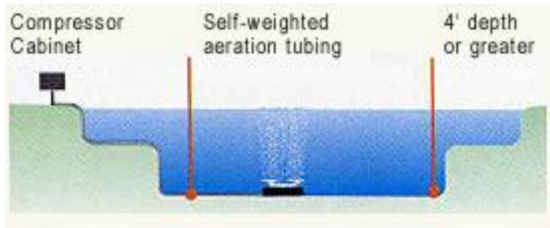
1. Facilities designed with permanent pools or containing permanent lakes shall have a water area of at least one-half (0.5) acre with a minimum depth of eight (8) feet over the majority of pond area when feasible based on pond bank slope requirements. If fish are to be used to keep the pond clean, a minimum depth of approximately ten (10) feet shall be maintained over at least 25 percent of the pond area. The remaining pond area shall have no extensive shallow areas, except as required to install the safety ramp, safety ledge, and BMPs as required below. Construction trash or debris shall not be placed within the permanent pool. The pond design shall be according to the City of Fishers Standard Construction Details.

2. A safety ramp exit from the lake may be required in some cases and shall have a minimum width of twenty (20) feet and exit slope of 6 horizontal to 1 vertical (6:1). The safety ramp shall be constructed of suitable material to prevent structural instability due to vehicles or wave action.

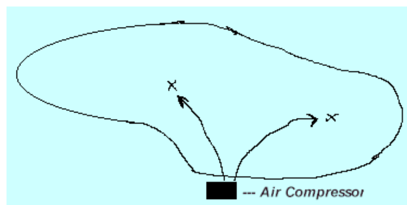
3. Periodic maintenance is required in lakes and ponds to control weed, algae, and larval growth. The facility shall also be designed to provide for the easy removal of sediment that will accumulate during periods of reservoir operation. A means of maintaining the designed water level of the lake during prolonged periods of dry weather may also be required. Fishers will not be responsible for pond maintenance.

4. Methods to prevent pond stagnation, including but not limited to surface or sub-surface aeration (diffusers) or destratification facilities should be included to limit surface water stagnation and algae growth. The figure below shows a typical diffuser aeration system that consists of a quiet air

compressor at the shore, aeration tubing, and one or more sets of diffuser head(s).



Irregularly shaped ponds should be treated as two or three separate ponds. Likewise, larger ponds will also need multiple aeration or diffuser units.



If aeration is considered, an appropriate Operations and Maintenance Manual (O&M) should be prepared for the benefit of the future responsible Homeowner's Association (HOA). Agreements for the perpetual operation and maintenance of aeration facilities should also be considered and incorporated into the (O &M) and/or the covenants and restrictions for the subdivision. Once ownership of a development has been transferred to the HOA, a copy of the BMP O&M should be signed by the HOA and the HOA should be made aware of all aeration maintenance responsibilities.

5. A note shall be placed upon the construction plans that indicates clay pond liners are required if significant sand or gravel stratifications are encountered during excavation of the pond.

E. Additional Requirements for Dry-Bottom Facility Design

In addition to general design requirements, detention facilities that will not contain a permanent pool of water shall comply with the following requirements:

1. Provisions shall be incorporated into facilities for complete interior drainage of dry bottom facilities, including a minimum 0.5% bottom slope (1% if practical) in all directions if tile underdrains are provided and a minimum of 1% if no underdrains are provided (underdrains are required unless impossible due to engineering constraints). A positive/gravity outlet is required for the underdrains in all dry-bottom detention facilities. Paved gutters will not be allowed within dry detention facilities.

2. For residential developments, the maximum planned depth of stormwater stored shall not exceed four (4) feet.

3. In excavated detention facilities, a minimum side slope of 3:1 shall be provided for stability.

G. Detention Facilities in Floodplains

Except for projects exempted under Article 3.02.D of the Resolution, no detention facilities are allowed to be placed within floodplains of any regulated drain or watercourse that has more than 25 acres of contributing drainage area, whether designated as such on FEMA maps or not.

H. Joint Development of Control Systems

Stormwater control systems may be planned and constructed jointly by two or more developers as long as compliance with the Resolution and Standards is maintained.

I. Diffused Outlets

When the allowable runoff is released in an area that is susceptible to flooding or erosion, the developer may be required to construct appropriate storm drains through such area to avert increased flood hazard caused by the concentration of allowable runoff at one point instead of the natural overland distribution. The requirement of diffused outlet drains shall be at the discretion of the Director of Engineering.

J. IDNR Requirements

All designs for basins to be constructed in the floodway of a stream with a drainage area of one square mile or more must also satisfy IDNR permit requirements.

K. Allowance for Sedimentation

Detention basins shall be designed with an additional ten (10) percent of available capacity to allow for sediment accumulation resulting from development and to permit the pond to function for reasonable periods between cleanings. Basins should be designed to collect sediment and debris in specific locations, such as a forebay, so that removal costs are kept to a minimum. For wet-bottom ponds, the sediment allowance may be provided below the permanent pool elevation. No construction trash or debris shall be allowed to be placed within the permanent pool. If the pond is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the pond and elevations and grades have been reestablished as noted in the accepted plans.

L. Maintenance

The routine maintenance of stormwater detention facilities (i.e. trash pickup, aeration, weed control, sediment removal, etc.) is the responsibility of the facility owner or the Homeowners' Association. In the event the owner or the Association fails to exercise its obligation, the City may perform the required maintenance and shall have the right to assess each lot in the subdivision a proportionate amount of the associated costs. If necessary, a Notice of Lien shall be filed against the affected lots. The lien shall be enforced in the same manner as a mortgage lien under Indiana law and, therefore, shall include reimbursement of attorney's fees, title expenses, interest, and costs of collection.

Chapter Seven

CONSTRUCTION SITES STORMWATER POLLUTION PREVENTION STANDARDS

The requirements contained in this Chapter are intended to prevent stormwater pollution resulting from soil erosion and sedimentation or from mishandling of solid and hazardous waste. Practices and measures included herein should assure that no foreign substance, (e.g. sediment, construction debris, chemicals) be transported from a site and allowed to enter any drainageway, whether intentionally or accidentally, by machinery, wind, rain, runoff, or other means. Minimize the potential for soil erosion by designing a development that fits the topography and soils of the site. Deep cuts and fills in areas with steep slopes should be avoided wherever possible, and natural contours should be followed as closely as possible.

A. POLLUTANTS OF CONCERN DURING CONSTRUCTION

The major pollutant of concern during construction is sediment. Natural erosion processes are accelerated at a project site by the construction process for a number of reasons, including the loss of surface vegetation and compaction damage to the soil structure itself, resulting in reduced infiltration and increased surface runoff. Clearing and grading operations also expose subsoils which are often poorly suited to re-establish vegetation, leading to longer term erosion problems.

Problems associated with construction site erosion include: transport of pollutants attached to displaced sediment; increased turbidity (reduced light) in receiving waters; and recreational use impairment. The deposited sediment may pose direct toxicity to wildlife, or smother existing spawning areas and habitat. This siltation also reduces the flow capacity of waterways, resulting in increased flood hazards to the public.

Other pollutants of concern during the construction process are hazardous wastes or hydrocarbons associated with the construction equipment or processes. Examples include concrete washoff, paints, solvents, and hydrocarbons from refueling operations. Poor control and handling of toxic construction materials pose an acute (short-term) or chronic (long-term) risk of death to aquatic life, wildlife, and the general public.

B. EROSION AND SEDIMENT CONTROL REQUIREMENTS

The following principles shall govern erosion and sediment control practices on all sites:

1. Project owner shall post the NOI along with the name, company name, telephone number, email address, and address of project site owner or local contact person. Also, a stamped set of construction site plans must be located and made available on site.

2. Sediment-laden water flowing from the site shall be detained by erosion control measures appropriate to minimize sedimentation.

3. Water shall not be discharged in a manner that causes erosion at or downstream of the point of discharge.

4. All access to building sites that cross a natural watercourse, drainage easement, or swale/channel shall have a culvert of appropriate size and be permitted by the appropriate state or federal agency such as IDEM, USACE, or IDNR.

5. Wastes or unused building materials, including but not limited to garbage, debris, cleaning wastes, wastewater, toxic materials, and hazardous substances, shall not be carried by runoff from a site. All wastes shall be disposed of in a proper manner within a dumpster or approved concrete washout containment system. Only concrete washout or mortar cleaning materials should be placed in the concrete washout containment. No construction trash or debris shall be allowed to be placed within the permanent pool of the detention/retention ponds. If the pond is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the pond and elevations and grades have been reestablished as noted in the accepted plans.

6. Sediment being tracked from a site onto public or private roadways shall be minimized. This shall be accomplished initially by a temporary gravel construction entrance, in addition to a well-planned layout of roads, stable access drives, and stable staging and parking areas.

7. Public or private roadways shall be kept cleared of accumulated sediment. Bulk clearing of sediment shall not include flushing the area with water. Clearing should be done by dry sweeping or vacuum techniques. For hard to remove sediment or other materials, water sprayers attached to a vacuum based street sweeper may be used as long as all water laden material is removed from the street by the vacuum system.

8. All storm drain inlets shall be protected against sedimentation with barriers meeting accepted criteria, standards, and specifications, or shall be equipped with temporary catch basin inserts and frequently cleaned. Inlet protection on existing road storm drains shall be below grate/grade practices with internal hanging baskets and overflow protection to prevent traffic hazards and ponding of water on public roadways.

9. Portable toilets shall be placed behind the curb, anchored, and located at least 50 feet from inlets or other conveyance systems where possible.

10. Runoff passing through a site from adjacent areas shall be controlled by diverting it around disturbed areas, where practical. Diverted runoff shall be conveyed in a manner that will not erode the channel and receiving areas. Alternatively, the existing channel may be left undisturbed or improved to prevent erosion or sedimentation from occurring.

11. Drainageways and swales shall be designed and adequately protected so that their final gradients and resultant velocities will not cause channel or outlet scouring.

12. Phasing of construction activities shall be used to minimize disturbance of large areas.

13. All disturbed ground left inactive for fifteen (15) or more days shall be stabilized by seeding/mulching, sodding, mulching, covering, or by other equivalent erosion control measures. If straw mulch is used, the strawshould be crimped into the soil or attached to the soil with a tackifying agent.

14. Temporary soil stockpiles shall be located in approved areas away from inlets or conveyance systems and properly protected with silt fence or temporarily stabilized.

15. Permanent pond banks, channels, swales, and slopes greater than 3:1 shall be permanently stabilized with erosion control blanket and seed immediately upon completion.

16. Permanent stabilization is achieved when a uniform layer of perennial vegetative cover is achieved over 100% of the disturbed area at a density of 70%.

17. Appropriate sediment and flow control practices shall be installed prior to any land disturbance and thereafter whenever necessary.

18. Flow control practices such as diversion berms, sediment basins, sediment traps, water bars, and rock check dams shall be designed/installed when appropriate per plan.

19. Natural features, including wetlands and sinkholes, shall be protected from pollutants associated with stormwater runoff.

20. Water from dewatering operations shall have a protected intake and shall outlet to a stabilized discharge point after being treated with a dewatering bag, well-point, or surface skimmer.

21. During the period of construction activity at a site, erosion control measures necessary to meet the requirements of the Resolution shall be maintained by the applicant.

22. Post-construction BMPs in finished development sections shall not be utilized as active construction BMPs for new development sections without appropriate active construction phase BMPs prior to discharge to the post-construction BMP. Designers shall utilize temporary practices such as sediment basins, sediment traps, etc. appropriate for the drainage area served as pre-treatment controls.

C. COMMON CONTROL PRACTICES

All erosion control and stormwater pollution prevention measures required to comply with the Resolution shall meet at a minimum the design criteria, standards, and specifications similar to or the same as those outlined in the "Indiana Stormwater Quality Manual" (ISWQM), published by the Indiana Department of Environmental Management, or other comparable and reputable references. However, the City of Fishers reserves the right to require alternative measures in the event that a specific standard or practice within the ISWQM does not meet the City's unique requirements. **Table 7-1** lists some of the more common and effective practices for preventing stormwater pollution from construction sites. Details of each practice can be found in the Indiana Stormwater Quality Manual**.**, or in **Appendix C**. These practices should be used to protect ***every*** potential pollution pathway to stormwater conveyances.

Table 7-1
Common Stormwater Pollution Control Practices for Construction Sites

Practice No.	BMP Description	Applicability	Fact Sheet
1	Site Assessment	All sites	ISWQM (Ch.2)
2	Development Of A Construction Sequence Schedule	All sites	ISWQM (Ch. 5)
3	Tree Preservation and Protection	Nearly all sites	ISWQM
4	Temporary Construction Ingress/Egress Pad	All sites	ISWQM
5	Wheel Wash	All sites	CN - 101
6	Silt Fence	Small drainage areas	ISWQM
7	Surface Roughening	Sites with slopes that are to be stabilized with vegetation	ISWQM
8	Temporary Seeding	Areas of bare soil where additional work is not scheduled to be performed for a minimum of 15 days	ISWQM
9	Mulching	Temporary surface stabilization	ISWQM
10	Erosion Control Blanket (Surface)	Temporary surface stabilization, anchor for mulch	ISWQM
11	Temporary Diversion	Up-slope and down-slope sides of construction site, above disturbed slopes within site	ISWQM
12	Rock Check Dam	2 acres maximum contributing drainage area	ISWQM
13	Temporary Slope Drain	Sites with cut or fill slopes	ISWQM
14	Geotextile Fabric Drop Inlet Protection	1 acre maximum contributing drainage area	ISWQM
15	Insert (Basket) Curb Inlet Protection	1 acre maximum contributing drainage area	ISWQM
16	Temporary Sediment Trap	5 acre maximum contributing drainage area	ISWQM
17	Temporary Dry Sediment Basin	30 acre maximum contributing drainage area	ISWQM
18	Dewatering Structures	Sites requiring dewatering	CN-102
19	Dust Control	All sites	ISWQM
20	Spill Prevention and Control	All sites	CN - 103
21	Solid Waste Management	All sites	CN - 104
22	Hazardous Waste Management	All sites	CN - 105

See ISWQM Chapter 7 (2007 or latest version), unless otherwise noted. (http://www.in.gov/idem/4899.htm)

D. INDIVIDUAL LOT CONTROLS

Although individual lots within a larger development may not appear to contribute as much sediment as the overall development, the cumulative effect of lot development is of concern. From the time construction on an individual lot begins, until the individual lot is stabilized, the builder must take steps to:

- protect adjacent properties from sedimentation
- prevent mud/sediment from depositing on the street
- protect drainageways from erosion and sedimentation
- prevent sediment laden water from entering storm sewer inlets.

The following information must be submitted to the City of Fishers, for review and acceptance, by the individual lot operator, whether owning the property or acting as the agent of the property owner, as part of a request for review and issuance of an Individual Lot Plot Plan Permit that must be obtained prior to the issuance of a building permit.

A. A lot plan sealed/signed by a professional land surveyor licensed in Indiana with following minimum requirements:
   i. Drainage Patterns and Swales
   ii. Flood Zone Designation
   iii. Proposed or Existing Structures tied to lot lines to nearest tenth of a foot.
   iv. Bearings and distances of lots including: set-back lines, square footage, easements, streets, alleys, sidewalks, building set-back lines, width of lots at building set-back line and lot grades.
   v. Proposed elevations required to nearest tenth that must be in accordance with approved subdivision plan (including Benchmark) for the following:
      a. entry way
      b. main floor
      c. top of foundation
      d. ground grade at each corner of building
      e. ground grade at lot corners
      f. grade at side yard
      g. slope of Driveway expressed as a percentage
      h. elevations of adjacent properties including top finished floor, lot and building corners.
   vi. A certified as-built with all the Lot Plan information and as-built information will be required for Occupancy. Any difference of over 0.5 feet, either vertically or horizontally between proposed and actual, shall be highlighted by the Indiana-registered land surveyor signing the as-built. If winter conditions do not allow final grading, a certificate of future compliance must be noted on as-built drawing.

B. Erosion and sediment control plan that, at a minimum, includes the following measures:
   i. Installation of a lot sign with lot number according to the Development Department requirements until the lot number or address is posted on a site building.
   ii. Installation and maintenance of a stable construction site access.
   iii. Installation and maintenance of appropriate perimeter erosion and sediment control measures prior to land disturbance.

iv. Minimization of sediment discharge and tracking from the lot.
v. Clean-up of sediment that is either tracked or washed onto roads. Bulk clearing of sediment shall not include flushing the area with water. Cleared sediment must be redistributed or disposed of in a manner that is in compliance with all applicable statutes and rules.
vi. Adjacent lots disturbed by an individual lot operator must be repaired and stabilized with temporary or permanent surface stabilization.
vii. Self-monitoring program including plan and procedures.

C. Certification of Compliance stating that the individual lot plan is consistent with the stormwater management permit, as approved by the City for the larger project.
D. Name, address, telephone number, and list of qualifications of the trained individual in charge of the mandatory stormwater pollution prevention self-monitoring program for the project site.

A standard erosion control plan for individual lots is provided in **Appendix B**. The standard plan includes perimeter silt fence, stabilized construction entrance, curb inlet protection, drop inlet protection, stockpile containment, stabilized drainage swales, downspout extensions, temporary seeding and mulching, and permanent vegetation. Every relevant measure should be installed at each individual lot site.

Construction sequence on individual lots should be as follows:

1. Post a lot sign according to the Development Department requirements denoting the lot number prior to the erosion control inspection. This lot sign must be clearly posted on the lot until the lot number and/or address can be posted on the structure.
2. Clearly delineate areas of trees, shrubs, and vegetation that are to be undisturbed. To prevent root damage, the areas delineated for tree protection should be at least the same diameter as the crown.
3. Install perimeter silt fence at construction limits. Position the fence to intercept runoff prior to entering drainage swales. Where slopes exceed 3:1, erosion control blanket or other methods may be required in lieu of silt fence if silt fence is not appropriate for the slope.
4. Avoid disturbing drainage swales if vegetation is established. If drainage swales are bare, install erosion control blankets or sod to immediately stabilize.
5. Install drop inlet protection for all inlets on or near the property.
6. Install curb inlet protection, on both sides of the road, for all inlets along the property frontage and along the frontage of adjacent lots, or install temporary catch basin inserts in each inlet and frequently clean.
7. Install a gravel construction entrance with a minimum thickness of six (6) inches of #2 stone underlain by an appropriate geotextile fabric that extends from the street to the building pad.
8. Perform primary grading operations.
9. Contain erosion from any soil stockpiles created on-site with silt fence around the base.
10. Establish temporary seeding and straw mulch on disturbed areas. Use erosion control blanket or properly formulated hydroseed/mulch for areas where slopes exceed 3:1.

11. Construct the home and install utilities.
12. Install downspout extenders once the roof and gutters have been constructed. Extenders should outlet to a stabilized area.
13. Re-seed any areas disturbed by construction and utilities installation with temporary seed mix within 3 days of completion of disturbance.
14. Grade the site to final elevations.
15. Install permanent seeding/straw,sod, erosion control blanket and seed, or a properly formulated mix of hydroseed.

All erosion and sediment control measures must be properly maintained throughout construction. Temporary and permanent seeding should be watered as needed until established. For further information on individual lot erosion and sediment control, please see the "Individual Lot Erosion and Sediment Control Plan and Certification" form in **Appendix B** or the IDNR, Division of Soil Conservation's pamphlet titled "Erosion and Sediment Control for Individual Building Sites".

Chapter Eight

POST-CONSTRUCTION STORMWATER QUALITY MANAGEMENT STANDARDS

A. INTRODUCTION

It is recognized that developed areas, as compared to undeveloped areas, generally have increased imperviousness, decreased infiltration rates, increased runoff rates, and increased concentrations of pollutants such as fertilizers, herbicides, greases, oil, salts and other pollutants. As new development and re-development continues within the corporate boundaries of the City of Fishers, measures must be taken to intercept and filter pollutants from stormwater runoff prior to reaching regional creeks, streams, and rivers. Through the use of appropriate Best Management Practices (BMPs), stormwater runoff will be filtered and harmful amounts of sediment, nutrients, and contaminants will be removed.

It is also recognized that another major source of pollution in many Indiana streams, including those within the corporate boundaries of the City of Fishers, is the streambank erosion associated with urbanizing watersheds. Stream channels develop their shape in response to the volume and rate of runoff that they receive from their contributing watersheds. Research has shown that in hydrologically stable watersheds, the stream flow responsible for most of the shaping of the channel (called the bankfull flow) occurs between every one to two years. When land is developed, the volume and rate of runoff from that land increases for these comparatively small flooding events that are not normally addressed by the conventional detention practices and the stream channel will adapt by changing its shape. As the stream channel works to reach a new stable shape, excess erosion occurs. As new development and re-development continues within the corporate boundaries of the City of Fishers, measures should be taken to minimize the impact of such development or re-development on streambank erosion. Through the use of appropriate Best Management Practices (BMPs), the volume and rate of runoff for channel-forming flows can be reduced in an attempt to minimize increased streambank erosion in the receiving streams and channels.

The management of stream erosion through channel protection and also water quality protection can be satisfied through a variety of methods that can be broadly categorized under two general approaches:

1. Conventional Approach
2. Low Impact Development (LID) Approach

This Chapter establishes standards for the selection and design of post-construction water quality and channel protection BMPs. The information provided in this Chapter establishes performance criteria for stormwater quality management and procedures to be followed when preparing a BMP plan for compliance. Ideally, post-construction BMPs should be sized to treat the channel protection volume (CPv), water quality volume (WQv), and for flow-through BMPs the water quality discharge rate (Qwq). For the conventional approach, the methodology for calculating the CPv, WQv, and Qwq values is provided in Section E of this Chapter. For the LID approach, alternative methods of calculating these values are provided in Section F of this Chapter.

B. POST-CONSTRUCTION BMPs PERFORMANCE CRITERIA

Channel protection is typically achieved by matching the post-construction runoff volume and rate to the pre-settlement (prior to any historical land conversion by man) condition for all runoff events up to the bankfull flow. The bankfull flow in most Indiana streams correlate with 1.5- to 2-year flood event flow. However, due to difficulties in determining the pre-settlement conditions, the net control of runoff resulting from a 1-year, 24-hour storm in proposed conditions (rather than the alternative method of determining increase in 2-year, 24-hour storm over pre-settlement conditions) is established as the City of Fishers standard for channel protection. At this time, meeting the Channel Protection Volume performance criteria is voluntary (but highly recommended) for the Conventional Approach.

The City of Fishers has also established a minimum standard that the measurement of the effectiveness of the control of post-construction stormwater runoff quality will be based on removal of floatables in stormwater runoff and treatment, to the maximum extent practicable, of all major pollutants of concern expected for the proposed land use and/or those identified in the Storm Water Pollution Prevention Plan for the site (including, if applicable, those pollutants found to be the cause of the receiving stream to be listed in IDEM 303(d) list) for the first inch of rainfall at the site. The above-noted “maximum extent practicable” criterion is subject to a minimum of 80% removal of Total Suspended Solids (TSS). These requirements are adopted as the basis of the City’s stormwater quality management program for all areas of the jurisdiction.

For the purpose of these Standards, the control of post-construction stormwater runoff quality is assumed satisfactory when the appropriate number of pre-approved structural BMPs (see Table 8-1 below), are utilized to meet the 80% TSS removal requirement. Note that multiple BMPs may need to be connected in series as not all meet the 80% TSS removal requirement alone.

C. POLLUTANTS OF CONCERN AFTER CONSTRUCTION STABILIZATION

There are three major sources of pollutants for a stabilized construction site:

- Deposition of atmospheric material (including wind-eroded material and dust)
- General urban pollution (thermal pollution, litter)
- Pollutants associated with specific land uses

It should be noted that some pollutants accumulate on impervious surfaces. This accumulated material is then subject to being washed into watercourses during storm events. It is for this reason that fish kills often occur during a rain event following a substantial rainless period. This is also the reason that the most hazardous driving conditions are realized after the initial onset of a storm event, when deposited oil has not yet washed into adjacent conveyance systems.

Post-construction pollutants of concern include:

- **Sediment** is the major pollutant of concern during active construction. Natural erosion processes are accelerated at a project site by the construction process for a number of reasons, including the loss of surface vegetation and compaction damage to the soil structure itself, resulting in reduced infiltration and increased surface runoff. After the construction is completed, other chemicals that are released to surface waters from industrial and municipal discharges and polluted runoff from urban and agricultural areas continue to accumulate to harmful levels in sediments.

- **Toxic chemicals** from illegal dumping and poor storage and handling of materials. Industrial sites pose the most highly variable source of this pollution due to the dependency of the specific process to the resulting pollution amounts and constituents. As during construction, these chemicals can pose acute (short-term) or chronic (long-term) risk to aquatic life, wildlife and the general public.

- **Bacteria** from illicit sanitary connections to storm sewer systems, combined sewers, leaking septic systems, wildlife and domestic animal waste. Bacteria pathogens pose a direct health risk to humans and aquatic life.

- **Nutrients** can be released from leaking septic systems or applied in the form of fertilizers. Golf courses, manicured landscapes and agricultural sources are the primary land uses associated with excess fertilization. Excessive nutrients in the local ecosystem are the source of algal blooms in ponds and lakes. These excessive nutrients also lead to acceleration of the eutrophication process, reducing the usable lifespan of these water bodies. Nitrogen and phosphorous are the primary nutrients of concern.

- **Oxygen demand** (biological or chemical) can be impacted by chemicals transported on sediment, by nutrients, and other pollutants (such as toxic chemicals). Reduced levels of oxygen impair or destroy aquatic life.

- **Oils and hydrocarbons** accumulate in streets from vehicles. They can also be associated with fueling stations and illicit dumping activities. Oils and hydrocarbons pose health risk to both aquatic and human health.

- **Litter, including floatables,** can result in a threat to aquatic life. The aesthetic impact can also reduce the quality of recreational use.

- **Metals** can be associated with vehicular activity (including certain brake dusts), buildings, construction material storage, and industrial activities. Metals are often toxic to aquatic life and threaten human health.

- **Chlorides** (salts) are historically associated with deicing activities. Chlorides are toxic to native aquatic life (verses saltwater aquatic life). Communities should consider a combination or cinders or sand to replace or supplement their deicing activities with chlorides. In addition, chloride stockpiles should remain covered.

- **Thermal effects** can be introduced by the removal of shade provided by riparian trees, as well as impervious channel linings, such as concrete, which release stored heat to water passing over them. Other sources of elevated temperature include effluent from power plant and industrial activities. Thermal pollution can threaten aquatic habitat, including fish species and beneficial water insects. Of particular concern are salmonoid streams, due to the effect of thermal pollution on spawning for this particular species.

D. WATER QUALITY CHARACTERISTICS BY LAND USE

Direct water quality sampling is not generally required at this time under the Phase II provisions. However, water quality characteristics are strongly tied to land use. For the purpose of these standards, all proposed developments and re-developments shall be assumed to involve increased levels of floatables, TSS, TP, TN, and metals. Additional pollutants may also be expected at certain types of developments and specific sites, as identified in the Storm Water Pollution Prevention Plan for the site (including, if applicable, those pollutants found to be the cause of the receiving stream to be listed in IDEM 303(d) list).

E. CONVENTIONAL APPROACH WATER QUALITY DESIGN PROCEDURES

The following procedures shall be followed according to the Conventional approach:

Step 1: Provide BMPs to address Channel Protection Volume (recommended)
In a conventional approach, the receiving channel can be protected through retaining (when possible) or the extended detention of the 1-year, 24-hour storm event on entire site (disturbed and undisturbed) tributary to each outlet. Therefore, even if not currently required by the City, it is highly recommended that the designer and the developer consider providing the Channel Protection detention/retention BMPs for the site.

If provided, Channel Protection Detention/Retention BMPs must be designed to store the channel protection volume. The channel protection volume, CPv, is the storage needed to retain or detain the runoff to the receiving stream from the 1-year, 24-hour rainfall.

The methodology for calculating the Channel Protection Volume (CPv) for each of site’s final outlets using computer models or manual calculation is as follows:

- Computer Model: Use acceptable computer models (listed in Chapter 2) to determine the total runoff volume for the site contributing to each site’s outlet, utilizing 1-year, 24 hour rainfall depth with Soil Conservation Service (SCS) type 2 storm distribution, drainage area, and the composite CN calculated for the site, according to the Soil Conservation Service (SCS) CN loss method along with SCS unitless hydrograph methodology.

- Manual Calculation: If calculating manually, use the following formula:

$$CPv\ (ft^3) = Qv \times 1/12 \times A$$

Where

A = total post-construction site area contributory to each outlet (ft^2)
Qv = Runoff Depth (in) = $(P - 0.2S)^2/(P + 0.8S)$
P = 1-Year, 24 Hr Rainfall (in)
S = (1000/CN) – 10

Both wet and dry extended detention may be used so long as only 10% of the maximum stored volume is left in the basin after 36 hours from maximum storage time and no more than 40% of the maximum stored volume is released within the first 12 hours. To ensure that adequate detention volume is available within the facility over the years, the facility should be designed for long-term (a minimum of 50 years) sediment accumulation. If long-term sediment accumulation cannot be adequately provided for in the pond, or if the pond is intended to provide sediment control during the construction phase of the project, forebays near inlets can be included to help manage sediment accumulation. Forebays do not require a hard maintenance surface and shall not be visibly disconnected from the pond by rip rap or other berm structures.

Since, by design, 90% of the original volume will be available within 48 hours of start of each storm event (assumed to be about 36 hours from when the Channel Protection pool is full), the volume in the pond associated with the channel protection (CPv) may be assumed empty for the purpose of peak flow detention analysis discussed in Chapter 6. In addition, the volume provided for channel protection would also satisfy the water quality volume (WQv) requirement provided that the facility meets the design criteria in the fact sheet to assure the performance criteria noted in Section B of this Chapter are met.

Step 2: Provide BMPS to address Water Quality Management

When the channel protection volume is controlled with BMPs that also meet the stormwater quality performance criteria in Section B, no additional calculation or BMP implementation is necessary. If the channel protection volume is not provided for the site or, if provided, is not controlled through practices that also meet the stormwater quality performance criteria in Section B, a stormwater quality-specific BMP will be required. The City of Fishers has designated a number of pre-approved structural BMP methods (listed in **Tables 8-1 through 8-6**) to be used alone or in combination to achieve the stormwater quality performance criteria noted in Section B of this Chapter for runoff generated from up to the first inch of rainfall on the entire site (disturbed and undisturbed) tributary to each outlet. Details regarding the applicability and design of these pre-approved BMPs, including the effectiveness of these BMPs in treating pollutants of concern (including, if applicable, those pollutants found to be the cause of the receiving stream to be listed in IDEM 303(d) list), are contained within fact sheets presented in **Appendix D1**. Additional information on recommended plant lists and recommended materials used for construction of stormwater BMPs are provided in **Appendix D2** and **Appendix D3**, respectively.

Innovative BMPs, including but not limited to, BMPs not previously accepted by the City must be certified by a professional engineer licensed in State of Indiana and approved through the City. ASTM standard methods must be followed when verifying performance of new measures. New BMPs, individually or in combination, must meet the performance criteria noted in Section B of this Chapter. All innovative BMPs must have a low to medium maintenance requirement to be considered by the City. Testing to establish the pollutant removal rate must be conducted by an independent testing facility, not the BMP manufacturer.

Note that a single BMP measure may not be adequate to achieve the water quality requirements (as noted above) for a project. It is for this reason that a "treatment train", a number of BMPs in series, is often required for a project. The pollutant removal efficiency of a number of BMPs in series may be determined from the following formula:

$E_{series} = 1 - (1-E_1)(1-E_2)(1-E_3)\ldots$

where,
E_{series} = Removal Efficiency of the BMP series combined (in decimal form)
E_1, E_2, E_3,… = Removal Efficiency of Units 1, 2,3, …, respectively (in decimal form)

If there is more than one onsite drainage area, the removal rate requirement discussed in Section B (above) shall apply to each drainage area, unless the runoff from the subareas converge on site in which case the removal rate can be demonstrated through calculation using a weighted average.

The following methodology shall be used to calculate the required Water Quality Volume (WQv) or the Water Quality Flow-through rate (Qwq) for each area/sub-area.

Water Quality Volume (WQv)
Water Quality Detention BMPs must be designed to store the water quality volume for treatment. The water quality volume, WQv, is the storage needed to capture and treat the runoff from the first one inch of rainfall. The water quality volume is equivalent to one inch of rainfall multiplied by the volumetric runoff coefficient (Rv) multiplied by the site area.

A calculation methodology similar to that described for the channel protection volume may be utilized, except that the rainfall depth (P) will be equal to 1, instead of the 1-year, 24-hour depth.

Alternatively, a simpler methodology may be used for calculation of WQv as follows:

$$WQv = (P)\,(Rv)\,(A) / 12$$

where:
WQv = water quality volume for each site's outlet (acre-feet)
P = 1 inch
Rv = volumetric runoff coefficient
A = area in acres

The volumetric runoff coefficient is a measure of imperviousness for the contributing area, and is calculated as:

$$Rv = 0.05 + 0.009(I)$$

Where:
I is the percent impervious cover

For example, a proposed commercial site will be designed to drain to three different outlets, with the following drainage areas and impervious percentages:

Subarea ID	On-site Contributing Area (acres)	Impervious Area %	Off-Site Contributing Area (acres)
A	7.5	80	0.0
B	4.3	75	0.0
C	6.0	77	0.0

Calculating the volumetric runoff coefficient for subareas A, B and C yields:

Rv (subarea A) = 0.05+0.009(80)=0.77
Rv (subarea B) = 0.05+0.009(75)=0.73
Rv (subarea C) = 0.05+0.009(77)=0.74

The water quality volumes for these three areas are then calculated as:

WQv (subarea A) = (1")(Rv)(A)/12=0.77(7.5)/12=0.47 acre-feet
WQv (subarea B) = 0.73(4.3)/12=0.26 acre-feet
WQv (subarea C) = 0.74(6.0)/12=0.37 acre-feet

Note that this example assumed no offsite sources of discharge through the water quality BMPs. If there were significant sources of off-site runoff (sometimes called runon for upstream areas draining to the site), the designer would have the option of bypassing off-site runoff around the on-site systems, or the detention BMP should be sized to treat the on-site channel protection volume plus the water quality volume for the off-site sources.

Flow-through BMP Sizing (Qwq)
Flow-through BMPs are designed to treat runoff at a peak design flow rate through the system. Examples of flow through BMPs include catch basin inserts, sand filters, and grassed channels. Another flow through BMP is a hydrodynamic separator or other similar type of device discussed in the Water Quality Devices Fact Sheet (Appendix D1).

Hydrodynamic separators are proprietary, and usually include an oil-water separation component. Hydrodynamic separators (i.e. Gravity or Manufactured Stormwater Quality Units) shall be off-line and must also remove all oil and floatable debris up to, and including, the Qwq calculated for each project. The acceptable treatment rate for these devices shall be based on the latest City of Indianapolis Stormwater Quality Selection Guide.

The following procedure should be used to estimate peak discharges for flow through BMPs (adopted from Maryland, 2000). It relies on the volume of runoff computed using the Small Storm Hydrology Method (Pitt, 1994) and utilizes the NRCS, TR-55 Method.

Using the WQv methodology, a corresponding Curve Number (CNwq) is computed utilizing the following equation:

$$CNwq = \frac{1000}{\left[10 + 5P + 10Qa - 10\sqrt{Qa^2 + 1.25QaP}\right]}$$

where:
CNwq = curve number for water quality storm event
P = 1” (rainfall for water quality storm event)
Qa = runoff volume, in inches = 1”×Rv = Rv (inches)
Rv=volumetric runoff coefficient (see previous section)

Due to the complexity of the above equation, the water quality curve number is represented as a function of percent imperviousness in **Figure 8-1**.

The water quality curve number, CNwq, is then used in conjunction with the standard calculated time-of-concentration, tc, and drainage area as the basis input for TR-55 calculations. Using the SCS Type II distribution for 1 inch of rainfall in 24-hours, the water quality release rate, Qwq, can then be calculated.

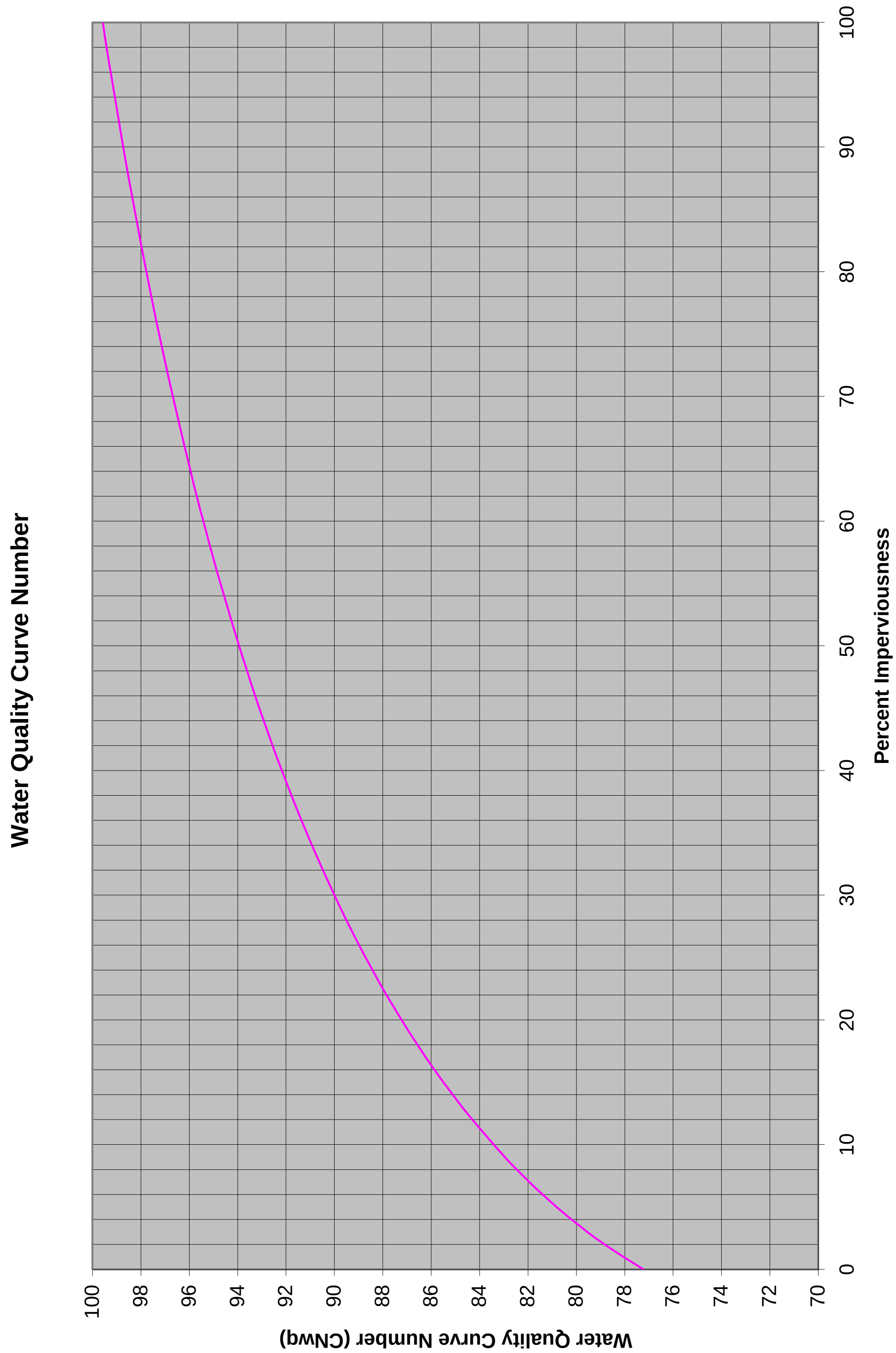
TABLE 8-1
Pre-approved Post-Construction BMPs for Conventional Approach

BMP[A]	Typical % TSS Removal Efficiency[B]	Maintenance Easement Requirements
Bioretention	90[C]	25 feet wide along the perimeter
Constructed Wetland	67[C]	25 feet wide along the outer perimeter of forebay & 30 feet wide along centerline of outlet
Underground Detention	70	20 feet wide strip from access easement to tank's access shaft & 30 feet wide along centerline of inlet and outlet
Extended Detention/Dry Pond	72	25 feet wide along the outer perimeter of forebay & 30 feet wide along centerline of outlet
Infiltration Basin	87	25 feet wide along the perimeter
Infiltration Trench	90[C]	25 feet wide along the perimeter
Constructed (Sand) Filter	70[C]	25 feet wide along the perimeter
Water Quality Device	VARIES[D]	20 feet wide strip from access easement to chamber's access shaft
Vegetated Filter Strip	78[C]	25 feet wide along the length on the pavement side
Vegetated Swale	81[C]	25 feet wide along the top of bank on one side
Wet Ponds/Retention Basin	80	25 feet wide along the outer perimeter of forebay & 30 feet wide along centerline of outlet

Notes:

A. Detailed specifications for these BMPs are provided in the fact sheets contained in Appendix D1.
B. Removal rates shown are based on typical results. Unless otherwise shown, data extracted by CBBEL from various data sources. These rates are also dependent on proper installation and maintenance. The ultimate responsibility for determining whether additional measures must be taken to meet the Resolution requirements for site-specific conditions rests with the applicant.
C. Based on IDEM Stormwater Quality Manual, 2007.
D. The removal rate for this category varies widely between various models and manufacturers. The acceptable treatment rate for these devices shall be based on the latest City of Indianapolis Stormwater Quality Selection Guide.

Figure 8-1
Curve Number Calculation for Water Quality Storm Event



F. LOW IMPACT DEVELOPMENT (LID) APPROACH DETENTION AND WATER QUALITY DESIGN PROCEDURES

Low Impact Development (LID) stormwater management design approaches are fundamentally different from conventional design approaches and challenge traditional thinking regarding development standards, watershed protection, and public participation. LID combines fundamental hydrologic concepts with many of today's common stormwater strategies, practices and techniques to reshape development patterns in a way that maintains natural watershed hydrologic functions. When the community has a user fee system based on imperviousness, the utilization of LID concepts also often results in a smaller stormwater user fee for non-residential lots. The five principles of LID are:

a) Conservation of existing natural and topographic features;
b) Minimization of land clearing and impervious surfaces;
c) Maintain or lengthen the pre-developed time of concentration;
d) Installation of integrated structural best management practices; and
e) Use of pollution prevention measures and practices.

Several methods for achieving the above requirements and principals are outlined below. In addition to methods described in this Standards Manual, several readily available references provide details on incorporating LID practices into site development. One of the most recent, comprehensive resources for incorporating LID practices into site development design is "Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers" available online at www.semcog.org/LowImpactDevelopment.aspx. The noted resource was used extensively for the development of the LID section in this Standards Manual and should be referenced for design related details of LID practice design.

Where practical, it is recommended that when underdrain is used to ensure positive drainage for an LID practice, the underdrain should be placed above the designed invert of the practice or bottom of the basin in an effort to infiltrate the water quality design storm as much as possible. This standard is intended to force stormwater to infiltrate into low permeability soil types by allowing it to remain within the LID basin until it is forced out by a large storm event. This design should be done so as to not allow water to pond at the surface of the practice. If the water quality storm cannot be stored below the surface of the practice without ponding, the underdrain elevation shall be adjusted accordingly. Plant types based on water affinity should be carefully considered when utilizing this approach.

The ultimate goal of LID approach is to retain as much as site runoff as possible through minimizing the disturbance, restoring disturbed areas, reducing imperviousness, and infiltration practices. However, the infiltration practices are most effective for smaller storms. As such, the City has set the Channel Protection Volume (CPv) both as the target and as the upper limit of recognition of runoff volume reduction through infiltration practices towards the overall site runoff control.

The following steps shall be followed for the LID approach:

Step 1: **Minimize Disturbed Areas and Protect Sensitive Areas**

- Map sensitive areas such as waterbodies, floodplains, and natural flow paths. Identify hydrologic soil types on the maps. Show elevations and identify critical slopes of 15 percent to 25 percent and above 25 percent. Show areas of known contamination. Also show existing structures and infrastructure.

- Determine the total area of impervious surface existing prior to development.

- Note the seasonal high groundwater level.

- Designate sensitive areas that are proposed to be protected as part of the proposed layout.

- Lay out the proposed development, minimizing disturbance and avoiding the sensitive areas.

- Utilize the non-structural BMPs listed in **Table 8-2** to properly protect sensitive areas so they maintain their pre-development state and runoff characteristics. Fact Sheets for these BMPs are provided in **Appendix D1**.

Table 8-2
Pre-approved BMPs with Treatment Area Reduction Recognitions for LID Approach

BMP[A]	Runoff Reduction Recognition[B]
Protect Sensitive Areas	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Protect Riparian Buffers	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Minimize Total Disturbed Area	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Reduce Impervious Surfaces	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Protect Natural Flow Pathways	Area (acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.
Cluster-Type Development	Area (undisturbed acres complying with the requirements of this BMP) can be subtracted from site development area for Channel Protection Volume and Water Quality Volume/Rate calculations.

Notes:

A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
B. If the LID track is pursued, reduced CNs (associated with pre-developed underlying soil types instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group) for areas protected by these BMPs may be used for determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8**.

- As shown in Table 8-2, when using the LID Approach, any area that is set aside and protected as described in those BMPs may be subtracted from site development area for purposes of determining Channel Protection Volume calculations and water quality volume/rate calculations.

- In addition, for determining the 10-year and 100-year runoff and peak discharges, the CN associated with the original, pre-development soil groups (instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group) may be used for these areas (see **Table 8-8**).

- The runoff reduction recognition only works with designs based on the Curve Number or CN method of analysis utilizing non-composite CN determination methods.

Step 2: <u>Restore Disturbed Areas</u>

- For the LID Approach, runoff reduction recognitions are used in the design process to emphasize the use of BMPs that, when applied, restore/alter the disturbed area in a way that reduces the volume of runoff from that area.

- Runoff reduction recognition is provided for the five BMPs listed in **Table 8-3** because they enhance the response of a piece of land to a storm event rather than treat the runoff that is generated. These BMPs are encouraged because they are relatively easy to implement over structural controls, require little if any maintenance, and the land they are applied to remains open to other uses.

- Runoff reduction recognition is applied by reducing the default CN value so that the amount of runoff generated from an event is reduced.

- The runoff reduction recognition only works with designs based on the Curve Number or CN method of analysis utilizing non-composite CN determination methods.

- Fact sheets for these BMPs are provided in Appendix D1.

Table 8-3
Pre-approved BMPs with Runoff Reduction Recognitions for Restoring Disturbed Areas as Part of LID Approach

BMP[A]	Runoff Reduction Recognition[B]
Minimize Soil Compaction	Area (acres complying with the requirements of this BMP) can be assigned a CN based on the Pre-developed soil group conditions instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group.
Protection of Existing Trees within disturbed areas (part of Protect Sensitive Areas)	Trees protected under the requirements of this BMP can be assigned a CN based on the Pre-developed soil group conditions at a rate of 800 square feet per tree instead of the normal requirement of assigning Post-developed CN according to the next lower infiltration soil group for the acres covered by the tree area.
Soil Amendment and Restoration	Area (acres complying with the requirements of this BMP) can be assigned a CN based on the Pre-developed soil group conditions instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group.
Native Revegetation	Proposed trees and shrubs to be planted under the requirements of this BMP can be assigned a CN based on the Pre-developed soil group conditions at a rate of 200 square feet per tree and 25 square feet per shrub instead of the normal requirement of assigning Post-developed CN according to the next lower infiltration soil group for the acres covered by the existing land use area.
Riparian Buffer Restoration	Proposed trees and shrubs to be planted under the requirements of this BMP can be assigned a CN based on the Pre-developed soil group conditions at a rate of 200 square feet per tree and 25 square feet per shrub instead of the normal requirement of assigning Post-developed CN according to the next lower infiltration soil group for the acres covered by the existing land use area.

Notes:

A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
B. If the LID track is pursued, reduced CNs (associated with pre-developed underlying soil types instead of the normal requirement of assigning the post-development CN according to the next lower infiltration soil group) for areas covered by these BMPs may be used for determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8**.

Step 3: <u>Minimize Imperviousness</u>

- The BMPs listed in **Table 8-4** are designed to reduce the volume of runoff from hard surfaces such as roads, sidewalks, parking areas, roofs, etc. For the LID Approach, runoff reduction recognition is used to encourage these practices and recognize their runoff reduction impacts. Fact Sheets for these BMPs are provided in Appendix D1.

Table 8-4
Pre-approved BMPs with Runoff Reduction Credits for Reducing Imperviousness as Part of LID Approach

BMP[A]	Runoff Reduction Recognition[B]
Porous Pavement[C]	Area covered by Porous Pavement with a minimum of 8 inch washed aggregate base may be assigned a weighted CN value of 87 (instead of CN of 98 normally used for impervious surfaces) for the purpose of Channel Protection Volume calculations. Use a weighted CN of 74 for the purpose of Water Quality Volume calculations, if needed. Note: If this BMP is specifically designed to provide permanent volume reduction through infiltration or through providing detention storage within the aggregate void, the volume reduction recognition discussed in Step 5 should be pursued instead of the CN reduction recognition, assuming CN of 98.
Vegetated Roof	Vegetated roofs are designed to reduce runoff volumes. However, the volume reduction is highly dependent on the media and planting used, with the calculation methods very complex at times. In lieu of calculating the volume reduction benefits, the roof area with vegetated roof with a minimum media depth of 4 inches and a void ratio of 0.3 (as described in the fact sheet) may be assigned a weighted CN of 87 (instead of CN of 98 normally used for impervious surfaces) for the purpose of Channel Protection Volume calculations. Use a weighted CN of 74 for the purpose of Water Quality Volume calculations, if needed.

Notes:

A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
B. If the LID track is pursued, reduced CNs for areas covered by these BMPs may be used for determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8** for weighted CN values used for such larger events.
C. The maximum allowable runoff reduction recognition for porous pavement shall be equal to the Channel Protection Volume corresponding to the area(s) utilizing this BMP.

- Although imperviousness reduction BMPs are encouraged throughout any new development or re-development, the runoff reduction recognition may only be considered where the following conditions are met:
  - The BMP must be in the common areas and covered by an easement or other agreement that assigns responsibility for its maintenance.
  - The BMP must be covered by a maintenance plan and agreement with assurances for the long-term availability of maintenance funds (such as funds held in a permanent escrow account) provided to the City in a form acceptable to the City.

Step 4: Calculate the amount of volume control needed for channel protection

- Determine the 1-year 24-hour rainfall from Table 2-5,

- Delineate subbasins in a manner that, at a minimum and to the extent possible, the pervious and impervious surfaces are in different subbasins

- Determine the disturbed drainage area for each subbasin by subtracting the protected area determined in Step 1 from total contributing drainage area.

- Assign CN to each cover type and land use, assigning "credited CN" for areas treated in Steps 2 and 3 instead of normal post-development CN that is determined based on the proposed land use and the next less infiltrating underlying soil group, when applicable. Published pre-determined weighted CN values shall not be utilized for LID Approach. This applies regardless of whether manual methods or computer modeling techniques are used.

- Determine the total post-development 1-year, 24-hour runoff volume for the entire site's disturbed areas through the use of acceptable computer models or manually as specified below. This is the net Channel Protection volume needing to be permanently removed by appropriate structural BMPs.

    - Computer Model: Use acceptable computer models (listed in Chapter 2) to determine the total runoff volume for the site, utilizing 1-year, 24 hour rainfall depth with Soil Conservation Service (SCS) type 2 storm distribution, drainage area, and CN determined above, according to the Soil Conservation Service (SCS) CN loss method along with SCS unitless hydrograph methodology.

    - Manual Calculation: If calculating manually, use the following formula:

        - Runoff Volume (ft3) for each cover type = Qv x 1/12 x A
          Where
          A = disturbed area of the particular cover type (ft^2)
          Qv = Runoff Depth (in) = $(P - 0.2S)^2/(P + 0.8S)$
          P = 1-Year, 24 Hr Rainfall (in)
          S = (1000/CN) – 10

        - Sum the individual volumes to obtain the total post-development runoff volume for area to be managed.

Step 5: Provide Distributed Volume Reduction/Infiltration Practices

- **Table 8-5** includes a list of the structural BMPs from potential BMPs that provide volume removal. Select and design structural BMPs that provide volume control to meet, when combined, the total net channel protection volume determined in Step 4.

Fact Sheets for these and other relevant post-construction structural BMPs are provided in Appendix D1.

Table 8-5
Pre-approved Structural BMPs with Permanent Volume Reduction Recognitions for Channel Protection as Part of LID Approach

BMP[A]	Channel Protection Volume Runoff Reduction Recognition[B]
Infiltration Practices (Infiltration Basin, Subsurface Infiltration Bed, Infiltration Trench, and Dry Well)	Volume reduction is achieved by surface storage volume (if included in the design), subsurface volume (if included in the design), and infiltration volume as described in the fact sheet. If an underdrain has to be used due to soil conditions, no recognition is granted for the "infiltration volume" portion unless the underdrain outlet elevation is set above the invert of the practice. The infiltration volume credited would then be determined based upon the elevation of the underdrain outlet.
Bioretention	Volume reduction is achieved by surface storage volume, soil storage volume, and infiltration bed volume as described in the fact sheet.
Vegetated Swale	Volume reduction is achieved by surface storage volume (if included in the design through inclusion of check dams) and active infiltration volume during the storm (when infiltration is expressly designed for as a purpose) as described in the fact sheet.

Notes:

A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
B. If the LID track is pursued, the volume reduction provided by these BMPs may be recognized towards determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8** for extent of runoff reduction recognition allowed for such larger events.

- The volume reduction BMPs may not be successfully implemented in every situation. See "Applicability and Limitation" discussions in each Fact Sheet. In order to qualify for recognition, the BMPs must also meet all the following:

  - Be in the common areas and covered by an easement or other agreement that assigns responsibility for its maintenance.

  - Be covered by a maintenance plan and agreement with assurances for the long-term availability of maintenance funds (such as funds held in a permanent escrow account) provided to the Homewowners Association or Property Owner in a form acceptable to the City.

  - Be constructed on undisturbed A or well-drained B soils (C/D soils do not qualify) or amended soil with underdrains, as needed. If underdrains are used, the bottom elevations of the underdrains should be above the seasonal high water table. Soil infiltration testing protocol, provided in **Appendix D-4**, must be followed to determine if infiltration BMPs are suitable at a site and to obtain the required data (such as soil conditions and depth of seasonal high water table) for infiltration design.

  - Be constructed in an area where the depth of seasonal high water table and any bedrock is more than a minimum of 2 feet (4 feet is desirable) from BMP bottom elevation.

  - Be constructed in a manner that any infiltration practices are adequately separated from basement foundations (50 feet up gradient, 10 feet down gradient), on-site septic systems/drainfields (100 feet), wells (50 feet), and other building elements that could be affected by infiltration systems. .

  - Be constructed outside of any 1-year (Zone 1) or 5–year (Zone 2) time of travel areas to public water supply wells, as defined by a modeled wellfield delineation performed in compliance with 327 IAC 8-4.1. When such delineation is not available, said practice must be at least 3,000 feet from the nearest public water supply well (unless applicant can demonstrate that the proposed practice will have no impacts on the water quality of the water supply well).

  - Final construction should be completed after the contributing drainage area has been stabilized.

  - Must contain erosion-protection features at the inflow to prevent scouring

  - Must contain a maintenance area near the inlet to collect large debris. Examples include small concrete aprons, catch basin inserts, or similar durable maintenance point.

- When the LID Approach is being pursued in all other aspects of the design but site limitations would not allow permanent volume reduction practices, channel protection volume should, at a minimum and as site limitations would allow, be accommodated through distributed storage solutions noted in Table 8-5 that also include underdrains as described in the appropriate Fact Sheets so that at a minimum they can act as both extended detention and filtration practices.

- **Calculation Methods for Recognizing Impacts of Distributed Storage on Overall Site's Peak Flow Detention Requirements:** when all the stated conditions above are met for volume-reduction distributed storage practices noted in Table 8-5, total volume provided for channel protection within distributed storage units (not to exceed the required channel protection volume calculated in Step 4) may be credited towards the site's overall detention requirements for peak (10-year and 100-year) flow control (see **Table 8-8**). Several methods are available to account for the noted runoff reduction recognition. A few common methods are listed below (other methods not noted below may also be used as appropriate):

- Method 1: Assume that the provided CPv in the distributed storage units (not to exceed the required CPv calculated in Step 4) will be stored below the detention pond's normal pool (below the lowest outlet). To simulate this condition, all the volumes in the elevation-storage table are increased by the provided CPv, an additional table entry is made as the first row with an artificial lower elevation and with zero for storage, and the reservoir's starting elevation is set at the noted artificial elevation.

- Method 2: Utilize the "Divert" option of the hydrologic model used to compute the inflow to the pond to simulate the diversion (abstraction) of the provided CPv (not to exceed the required CPv calculated in Step 4) from the detention pond inflow before the remaining flood hydrograph is routed through the detention system. To accomplish this, the model should have capability to simulate diversion with a volume cap option.

- Method 3: Explicitly model the distributed storage features as a network of storage and conveyance units through the use of computer programs that can correctly model interconnected storage.

Step 6: Provide Additional (as-needed) Extended Detention Practices

- When the LID Approach is being pursued in all other aspects of the design but site limitations would not allow adequate distributed volume reduction practices noted in Step 5 (with or without underdrain), then a constructed wetland or a wet-bottom extended detention facility along with incorporation of an appropriate wetland fringe should be utilized as listed in **Table 8-6**. If designed properly, such a facility can be incorporated into a multi-purpose facility to control channel protection volume, water quality volume, and 100-year peak flow rate. Note that since by design conditions of a wet-bottom extended detention facility, 90% of the original volume will be available within 48 hours of each storm event, the volume in the pond associated with the channel protection may be assumed empty for the purpose of peak flow detention analysis discussed in Chapter 6 of these Standards (see **Table 8-8**).

Table 8-6
Pre-approved BMPs with Additional, As-needed Extended Detention Runoff Reduction Recognitions for Channel Protection as Part of LID Approach

BMP[A]	Runoff Reduction Recognition[B]
Constructed Wetland	The volume of the supplementary extended detention, in lieu of permanent volume reduction, is credited towards meeting Channel Protection Volume requirements so long as only 10% of the maximum stored volume is left in the basin after 36 hours from maximum storage time and no more than 40% from the maximum stored volume is released within the first 12 hours.
Extended Detention Wet/Dry Pond	The volume of the supplementary extended detention, in lieu of permanent volume reduction, is credited towards meeting Channel Protection Volume requirements so long as only 10% of the maximum stored volume is left in the basin after 36 hours from maximum storage time and no more than 40% from the maximum stored volume is released within the first 12 hours.

Notes:

A. In using and crediting these BMPs, applicants must meet the review criteria located within the discussion of each BMP provided in Appendix D1.
B. If the LID track is pursued, the volume reduction provided by these BMPs may be recognized towards determining the post-developed runoff rates and volumes for larger events (up to and including the 100-year event). See **Table 8-8** for extent of runoff reduction recognition allowed for such larger events.

Step 7: <u>Determine Water Quality Volume and Provide, As-needed, Additional Water Quality BMPs</u>

- The expected treatment of many BMPs applied to LID designs is based on removing solids. Many pollutants are attached to solids or are removed by similar treatment mechanisms. Therefore, removing solids can act as a surrogate for the expected removal of other particulate pollutants. Often multiple BMPs will be necessary to remove successively smaller particle sizes to achieve the highest level of treatment.

- When the CPv is controlled with BMPs that also meet the stormwater quality performance criteria in Section B, often no additional calculation or BMP implementation is necessary. If the channel protection volume is not controlled through practices that also meet the stormwater quality performance criteria in Section B, calculate the water quality volume that provides for the treatment of the first inch of rainfall on the site's disturbed areas as discussed below.

- The methodology for determining the design water quality volume or rate for the LID Approach is the same as that described for CPv calculation described in Step 4, except the rainfall depth for Water Quality will be 1 inch instead of the 1-year, 24-hour rainfall depth used for calculating the CPv. A few considerations specific to Water Quality Volume/Rate calculations are as follows:

- Time of Concentration in the case of LID design is the time it takes a drop of water to move from the furthest point in the disturbed area to its discharge from the disturbed area.

- Computer Model: If using acceptable computer models, perform the same procedure as that performed for calculating CPv in Step 4, but for 1 inch of rainfall depth.

- Manual Calculation: If calculating manually, use the following formula:

  - Runoff Volume (ft^3) for each cover type = Qv x 1/12 x A
    Where
    A = disturbed area of the particular cover type (ft^2)
    Qv = Runoff Depth (in) = $(P – 0.2S)^2/(P + 0.8S)$
    P = 1 inch
    S = (1000/CN) – 10
  - Peak Runoff Rate (ft^3/sec) = qu x A x Qv x1/43,560
    Where
    A = disturbed area of the particular cover type (ft^2)
    Qv = Runoff Depth (in) calculated in previous step
    q_u = Unit Peak Discharge (cfs/mi^2/in), determined from TR-55 Exhibit 4-II
  - Sum the individual volumes and peak runoff rates to obtain the total design post-development water quality runoff volume and rate.

- Determine the total post-development water quality runoff volume and rate for the entire site's disturbed areas. These are the design post-development water quality runoff volume and rate needing to be treated.

- Select BMPs from the list provided in Table 8-1 that will meet the performance criteria noted in Section B of this Chapter. Often, multiple types of BMPs used in series will be required to provide adequate treatment. Design the BMPs in conjunction with any detention control that is needed for peak rate control of larger floods (100-year), if possible.

Step 8: <u>Complete the LID Approach Utilization Summary Form</u>

- As the final step of the LID Approach, a summary of non-structural and structural BMPs utilized, as part of the LID Approach, in the site design of a particular development site is provided in **Table 8-7** and submitted as part of the permit request package.

- The presence of Table 8-7 in the submittal package and the information contained in the form would alert the plan reviewer that the LID Approach is being used to meet the post-construction stormwater quality requirements of the site and that the overall site design as well as peak discharge and detention calculations should be reviewed with the impacts of LID Approach in mind.

Table 8-7
LID Approach Summary Checklist

This checklist is a tool to allow both the regulatory agency and the Developer to reference various LID measures implemented within the development in order to meet the development's Post Construction Stormwater Management requirements.

Project Name: **Engineer:** **Developer:**

Total Site Area: ___________________________sf
Proposed Earth Disturbance Area: ___________________________sf
Existing Impervious Area: ___________________________sf

LID Approach Step	Potential BMPs	√	Total Surface Area (sf) of LID Measure/BMP	Plan Pg # of LID Measure	Drainage Report Pg # of Calculations for LID Measure
1. Minimize Disturbed Areas	Protect Sensitive Areas				
	Protect Riparian Buffers				
	Protect Natural Flow Pathways				
	Minimize Total Disturbed Area				
	Reduce Impervious Surfaces				
	Cluster-Type Development				
2. Restore Disturbed Areas	Minimize Soil Compaction				
	Protect Trees in Disturbed Areas				
	Soil Amendment and/or Restoration				
	Native Revegetation				
	Riparian Buffer Restoration				
3. Minimize Imperviousness	Porous Pavement				
	Vegetated Roof				
4. Determine Volume Control Needed for Channel Protection	N/A (calculation step only)		**N/A**		
5. Provide Distributed Retention/Infiltration Practices	Infiltration Practices*				
	Bio-retention				
	Vegetated Swale				
6. Additional (as-needed) Extended Detention Practices	Constructed Wetland		**N/A**		
	Extended Detention Wet/Dry Pond		**N/A**		
7. Additional (as-needed) Water Quality BMPs	Pre-approved BMPs noted in Table 8-1 for conventional method		**N/A**		
Additional Flood Peak Control (2yr-100yr)	Detention Pond (wet/dry/underground)		**N/A**		

Total Surface Area of LID Measures ______________________ sf
Proposed Final Impervious Surface Area ______________________ sf
Percent of Total Site Area Covered by LID ______________________%

Note: Not all LID measures are necessary or appropriate for every site. It is imperative that proper site assessments and due diligence is completed by the Developer and/or Engineer prior to design.

*: Infiltration Practices include: Infiltration Basins, Subsurface Infiltration Beds or Trenches, and Dry Wells

Summary of Runoff Reduction Recognitions for Water Quality Volume, Channel Protection, and Peak Flow Control Detention Volume for LID approach

As discussed throughout this Section, to encourage LID approach for stormwater management, runoff reduction recognitions towards all three major stormwater management requirements, i.e., Water Quality, Channel Protection, and Peak Runoff Detention, are associated with various BMPs as noted through the above 8-step process. These runoff reduction recognitions are summarized in **Table 8-8**.

Table 8-8
Summary of Runoff Reduction Recognitions for Pre-approved BMPS Used in the LID Approach

Implementation Order	DESCRIPTION	POTENTIAL BMPS	RECOGNITION/CREDIT FOR POST-CONSTRUCTION WATER QUALITY CALCULATIONS		RECOGNITION/CREDIT FOR WATER QUANTITY (DETENTION AND STORM DRAIN) CALCULATIONS
			WATER QUALITY VOLUME	CHANNEL PROTECTION VOLUME	
1	Minimize Disturbed Areas	• Protect Sensitive Areas • Protect Riparian Buffers • Minimize Total Disturbed Area • Protect Natural Flow Pathways • Reduce Impervious Surfaces • Cluster-Type Development	Full recognition through allowing to use "disturbed surface area" only for all calculations	Full recognition through allowing to use "disturbed surface area" only for all calculations	Full recognition through allowing CN for the undisturbed, protected area to be calculated based on pre-developed underlying soil types
2	Restore Disturbed Areas	• Minimize Soil Compaction • Protection of Existing Trees within disturbed areas (part of Minimize Total Disturbed Area) • Soil Amendment and Restoration • Native Revegetation • Riparian Buffer Restoration	Full recognition through allowing CN for the restored/protected area to be calculated based on pre-developed underlying soil types	Full recognition through allowing CN for the restored/protected area to be calculated based on pre-developed underlying soil types	Full recognition through allowing CN for the restored/protected area to be calculated based on pre-developed underlying soil types
3	Minimize Imperviousness	• Porous Pavement	Full recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (74 instead of 98) AND full recognition of the stored volume (if provided for in the design) and WQ treatment, if designed as a true infiltration practice (no underdrain/ or extended 24-48 hrs release)	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (87 instead of 98) AND full recognition of the stored volume (if provided for in the design), if designed as a true infiltration practice (no underdrain/ or extended 24-48 hrs release)	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on pre-set values (89 for 10-year and 90 for 100-year calculations instead of using 98) and full recognition of the stored volume (if provided for in the design), on a case by case basis, treated as an underground detention, up to the Channel Protection Volume corresponding to the area(s) using this BMP.
		• Vegetated Roof	Full recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (74 instead of 98) AND full recognition of the stored volume (if provided for in the design) and/or WQ treatment if designed for	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value (87 instead of 98)	Partial (weighted) recognition of perviousness through allowing CN for the application area to be calculated based on a pre-set value 89 for 10-year and 90 for 100-year calculations instead of using 98)
4	Provide Distributed Volume Reduction/Infiltration Practices (or Filtration Practices, if underdrains have to be provided) in Common Areas	• Infiltration Practices (Infiltration Basin, Subsurface Infiltration Bed, Infiltration Trench, and Dry Well) • Bioretention • Vegetated Swale	Full recognition of perviousness through allowing CN for the application area to be calculated based on cover type and underlying soil AND full recognition of the retained volume (if provided for in the design) and/or WQ treatment if designed for	Full recognition of retained volume if designed as true infiltration practice (on appropriate soil and no underdrain/ or extended 24-48 hrs release)	Limited recognition of retained volume (up to the Channel Protection Volume) if designed as true infiltration practice (on appropriate soil and no underdrain/ or extended 24-48 hrs release)
5	Provide, As-needed, Additional Extended Detention Practices in Common Areas	• Constructed Wetland • Extended Detention Wet/Dry Pond	full recognition of the stored volume (with extended 24-48 hrs release) and/or WQ treatment if designed for	Full Recognition of stored volume (with extended 24-48 hrs release)	Full Recognition of stored volume (with extended 24-48 hrs release)
6	Provide, As needed, Additional Water Quality BMPs	• Pre-approved BMPs noted in Table 8-1 for conventional method	Full recognition of WQ treatment	N/A	N/A

G. SPECIAL PROVISIONS FOR "HOT SPOT" LAND USES

For all those projects involving land uses considered to be high pollutant producers or "hot spots" (see **Table 8-9** e.g., vehicle service and maintenance facilities, vehicle salvage yards and recycling facilities, vehicle and equipment cleaning facilities, fleet storage areas for buses, trucks, etc., industrial/commercial or any hazardous waste storage areas or areas that generate such wastes, industrial sites, restaurants and convenience stores, any activity involving chemical mixing or loading/unloading, outdoor liquid container storage, public works storage areas, commercial container nurseries, and some high traffic retail uses characterized by frequent vehicle turnover), additional water quality requirements may be imposed by the City in addition to those included in water quality criteria in order to remove potential pollutant loadings from entering either groundwater or surface water systems. These pre-treatment requirements are included in **Table 8-9** and **Table 8-10**.

Table 8-9
Pre-Treatment options for Stormwater Hot Spots

Stormwater Hot Spots	Minimum Pre-Treatment Options
Vehicle Maintenance and Repair Facilities	A, E, F, G
Vehicle Fueling Stations	A, D, G
Drive-through Restaurants, Pharmacies, Convenience Stores	B, C, D, I, K
Outdoor Chemical Mixing or Handling	G, H
Outdoor Storage of Liquids	G
Commercial Nursery Operations	I, J, L
Other Uses or Activities Designated by Appropriate Authority	As Required

Table 8-10
Minimum Pre-Treatment Options

Minimum Pre-Treatment Options	
A	Oil/Water Separators / Hydrodynamic Separators
B	Sediment Traps/Catch Basin Sumps
C	Trash/Debris Collectors in Catch Basins
D	Water Quality Inserts for Inlets
E	Use of Drip Pans and/or Dry Sweep Material under Vehicles/Equipment
F	Use of Absorbent Devices to Reduce Liquid Releases
G	Spill Prevention and Response Program
H	Diversion of Stormwater away from Potential Contamination Areas
I	Vegetated Swales/Filter Strips
J	Constructed Wetlands
K	Stormwater Filters (Sand, Peat, Compost, etc.)
L	Stormwater Collection and Reuse (especially for irrigation)
M	BMPs that are a part of a Stormwater Pollution Prevention Plan (SWPPP) under a NPDES Permit

H. CONSTRUCTION SEQUENCING CONSIDERATIONS

BMPs noted in this chapter refer to post-construction BMPs, which continue to treat stormwater after construction has been completed and the site has been stabilized. Installing certain BMPs, such as bioretention areas and sand filters, prior to stabilization can cause failure of the measure due to clogging from sediment. If such BMPs are installed prior to site stabilization, they should be protected by traditional erosion control measures.

In those instances, the construction sequence must require that the pond is cleaned out with pertinent elevations and storage and treatment capacities reestablished as noted in the accepted stormwater management plan.

I. Inspection and Maintenance Requirements

Subsequent to successful installation of Post-construction BMPs, they need to be inspected and maintained regularly in accordance with the Operation and Maintenance Manual required to be prepared for each BMP. An operations and maintenance (O&M) manual for all private infrastructure, including but not limited to pipes, ponds, ditches, and BMPs (when required), shall be submitted for the final plan approval and permit process. The manual will become a maintenance guide for the drainage infrastructure once development is complete. The final O&M manual will be provided to the City in both hard copy and digital formats. The O&M manual maintenance agreement along with a site map showing the BMP locations (clearly labeled as "Stormwater BMP") shall be recorded with the final plat. The O&M manual will include the following:

1. Owner name, address, business phone number, home phone number, email address, cellular phone number, pager number;
2. Site drawings (8½" by 11" or 11" by 17"), showing both plan and cross-section views, showing the infrastructure and applicable features, including the BMPs, dimensions, easements, outlet works, forebays, signage, etc., as well as an overall site map of the development showing all structures;
3. Guidance on owner-required periodic inspections;
4. Requirement of owner to perform maintenance specified by City inspection, if any;
5. Guidance on routine maintenance, including mowing, weed trimming, litter removal, woody growth removal, signage, weed spraying and hand pulling, mulching, removal of invasive species, plant trimming, etc.;
6. Guidance on remedial maintenance; such as inlet replacement, outlet works maintenance, etc.;
7. Guidance on sediment and trash removal, both narrative and graphical, describing when sediment removal should occur in order to insure that BMPs and other infrastructure remain effective as water quality and/or quantity control devices;
8. A statement that the City's representatives have the right to enter the property to inspect the infrastructure;
9. A tabular schedule showing inspection and maintenance requirements; and
10. Identification of the property owner as the party responsible for all maintenance, including cost.

11. Identification of the future property owner such as Home Owners Association (HOA) or Property Owners Association (POA).
12. A signed affidavit by the existing owner at the time of development that a copy of the O&M Manual will be given to the HOA board at the time of the property transfer from developer over to the HOA or POA and that the board will be properly educated of their responsibilities in regard to maintenance of the detention and BMP facilities.

Inspection checklists for various types of BMPs are provided in **Appendix D5**. A sample Stormwater Management Maintenance Agreement is provided in **Appendix D6**. This agreement will need to be customized, signed, notarized, and recorded so that it can be a part of the property's deed.

Installation and maintenance of appropriate signage of all green infrastructure BMP sites shall also be required both to alert the maintenance crew and to educate the public.

Since the proper perpetual maintenance of post-construction BMPs, especially the green infrastructure, is so crucial to proper operation of such BMPs, in addition to the maintenance agreement discussed above, the developer is required to establish a permanent maintenance escrow account and subsequently transfer it to the future property owner's association or similar entity to cover the cost of annual maintenance of the post-construction BMPs in perpetuity.

The established escrow account can be spent solely for sediment removal, structural, biological or vegetative replacement or removal, invasive species or weed management, mulching, major repair, or reconstruction of the stormwater management measures and devices of the particular site plan or subdivision. If stormwater management facilities are not performing adequately or as intended or are not properly maintained, the City, in its sole discretion, may remedy the situation, and in such instances the City shall be fully reimbursed from the escrow account. Escrowed funds may be spent by the association for sediment removal, structural, biological or vegetative replacement or removal, invasive species or weed spraying and/or removal/trimming, mulching, major repair, and reconstruction of the stormwater management facilities; provided that, the City shall first consent to the expenditure. Note that the list of eligible expenses excludes routine mowing, landscaping, pruning, and other similar activities that have traditionally and continue to be expected of the entity controlling the land to fund.

Initially, the developer's contribution shall fund the escrow account. Prior to plat recordation or issuance of construction plan approval/permits, whichever shall first occur, the developer shall pay into the escrow account an amount equal to fifteen (15) per cent of the estimated initial construction cost of the stormwater control facilities. This amount shall remain in the escrow account and shall be transferred to the future property owner's association or similar entity after the developer receives the NOT for the project. Note that the establishment and dedication of the above referenced maintenance escrow account is in addition to the 3-year maintenance bond/assurance required by theResolution following the issuance of a "verified" NOT.

Once the NOT is granted for the project and the maintenance of the site has been turned over to the property owner/property owner's association or similar entity, the subsequent required annual funding of the escrow account shall be the responsibility of the property owner association. A portion of the annual assessments of the property owners association shall include an allocation into the escrow account. Any funds drawn down from the escrow account shall be replaced in accordance with the schedule of anticipated work used to create the budget. The property owner's association or similar entity shall report the balance and financial activities of the escrow account to the City on an annual basis in the manner acceptable to City.

REFERENCES

Southeast Michigan Council of Governments (SEMCOG), Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers, Detroit, Michigan, 2008.

Chapter Nine

MISCELLANEOUS REQUIREMENTS

A. GRADING AND BUILDING PAD ELEVATIONS

Minimum Federal and State Requirements

For all structures located in the Special Flood Hazards Area (SFHA) as shown on the FEMA maps, the Lowest Floor elevation, including basement, shall be at or above the flood protection grade (FPG) and therefore have a minimum of 2 feet of freeboard above the 100-year flood elevation. Additional requirements for buildings within SFHA are contained in the City of Fishers Unified Development Ordinance Floodplain Standards.

Additional Local Requirements

FPG for all buildings located within or adjacent to SFHA shall be shown on the secondary plat.

For all structures located outside FEMA or IDNR designated floodplains that are subject to flooding from a detention/retention pond, the lowest adjacent grade (LAG) of all residential, commercial, or industrial buildings shall have a minimum of 2 feet of freeboard above the 100-year flood elevation or the emergency overflow weir elevation, whichever is higher.

For all structures located outside FEMA or IDNR designated floodplains that are subject to flooding from an open ditch, the LAG of all residential, commercial, or industrial buildings shall have a minimum of 2 feet of freeboard above the 100-year flood elevation.

For all structures fronting a flooding source other than a swale or an emergency flood route, the floor of any basements or crawl spaces (if provided) shall be a minimum of 1 foot above the normal pool level (if pond) or the 2-year flood level (if a stream or an open ditch). In addition, special considerations, based on detailed geotechnical analysis, should be made prior to considering placement of any basement below the 100-year flood elevation of an adjacent flooding source or pond.

For all structures adjacent to an emergency flood route (also referred to as overflow path/ponding areas), the minimum adjacent grade of the portion of the structure (the ground elevation next to the building after construction is completed) that sits adjacent to the emergency flood route or may be subject to flooding by the emergency flood route shall be a minimum of 1 foot above the estimated 100-year elevation of the emergency flood route assuming that all stormwater inlets and pipes are fully clogged, with no discharge into the storm sewer system. The building adjacent grade requirements (including default elevations above the overflow route bottom) for buildings adjacent to overflow path/ponding areas are further discussed in Chapters 4 of this Manual.

For all structures adjacent to a road, the building's lowest entry elevation that is adjacent to and facing a road shall be a minimum of 1 foot above the road elevation (elevation of the gutter at the center of the lot) so that the road drainage is not directed against the building.

There shall be a positive slope drainage away from the building with maximum yard slopes that are 3:1 where soil has been disturbed during construction processes. Finished floor elevation or the lowest building entry elevation must be no less than 6 inches above finished grade around the building.

B. LOT DRAINAGE

All lots shall be laid out so as to provide drainage away from all buildings, and individual lot drainage shall be coordinated with the general stormwater drainage pattern for the subdivision. Drainage shall be designed so as to avoid the concentration of stormwater runoff from a lot onto adjacent lots. Each lot owner shall maintain the lot grade, as it relates to stormwater drainage, in compliance with the approved construction plans. Any deviation from that plan shall be remedied by the lot owner through other means or the lot grade shall be returned to its original grade. For lots developed in areas without an approved subdivision plan or for subdivision plans with insufficient drainage plan detail, new lots shall avoid concentrating water onto adjacent lots and/or provide an adequate drainage system to prevent water from cascading onto adjacent lots.

No part of the lot area of any lot may contain land that is utilized as retention or detention facility or drainage pond, contains a watercourse, or is within a floodway. Where a watercourse separates the buildable area of the lot from the street by which it has access, provisions shall be made for the installation of a culvert or other appropriate structure, as approved by the City. If a subdivision contains an existing or to be developed waterbody, watercourse, or portion thereof, appropriate documentary assurances acceptable to the City shall be provided for the maintenance of such waterbody or watercourse.

It shall be the property owners' responsibility to maintain the natural features on their lots and to take preventive measures against any and all erosion and/or deterioration of natural or manmade features on their lots.

C. ACCEPTABLE OUTLET AND ADJOINING PROPERTY IMPACTS POLICIES

Design and construction of the stormwater facility shall provide for the discharge of the stormwater runoff from off-site land areas as well as the stormwater from the area being developed (on-site land areas) to an acceptable outlet(s) (as determined by the City) having capacity to receive upstream (off-site) and on-site drainage. A Roadside Ditch is generally not considered an adequate outlet. The flow path from the development outfall(s) to a regulated drain, a City storm drain, or natural watercourse (as determined or approved by the City) shall be provided on an exhibit that includes topographic information. Any existing field tile encountered during the construction shall also be incorporated into the proposed stormwater drainage system or tied to an acceptable outlet.

Where the outfall from the stormwater drainage system of any development flows through real estate owned by others prior to reaching a regulated drain or watercourse, no approval shall be granted for such drainage system until all owners of real estate and/or tenants crossed by the outfall either consent in writing to the use of their real estate or are notified of a hearing relevant to the proposed use. Notification of the time and place of the hearing shall be made in person or by certified mail at least ten (10) days prior to the hearing. Proof of notice to each landowner shall be filed by affidavit with the City prior to the hearing. In addition, no activities conducted as part of the development shall be allowed to obstruct the free flow of floodwaters from an upstream property.

If an adequate outlet is not located on site, then off-site drainage improvements may be required. Those improvements may include, but are not limited to, extending storm sewers, clearing, dredging and/or removal of obstructions to open drains or natural water courses, and the removal or replacement of undersized culvert pipes as required by the City.

D. NO NET LOSS FLOODPLAIN STORAGE POLICY

Floodplains exist adjacent to all natural and man-made streams, regardless of contributing drainage area or whether they have been previously identified or mapped. Due to potential impacts of floodplain loss on peak flows in streams and on the environment, disturbance to floodplains should be avoided. When the avoidance of floodplain disturbance is not practical, the natural functions of the floodplain should be preserved to the extent possible.

In an attempt to strike a balance between the legitimate need for economic development within the City corporate boundaries and the need to preserve the natural functions of floodplains to the extent possible, when disturbance within floodplain cannot be avoided, compensatory excavation equivalent to the floodplain storage lost shall be required for all activities within floodplain of streams located in the City where drainage area of the stream is equal to or larger than one square mile. The City may alter the compensation ratio, based on extenuating circumstances, for a specific project.

General Requirements

Note that by definition, compensatory storage is the replacement of the existing floodplain and, in rare exceptions, the floodway storage lost due to fill. Compensatory storage is required when a portion of the floodplain is filled, occupied by a structure, or when as a result of a project a change in the channel hydraulics occurs that reduces the existing available floodplain storage. Compensatory storage must:

- Be provided regardless of whether the flooding source is mapped or whether flood elevations are published or not. When flood elevations are not available for a flooding source that has a drainage area equal to or larger than one (1) square miles (640 acres), the applicant is to determine the 10-year and 100-year flood elevations at the site and get them approved by the IDNR prior to use for floodplain compensation calculations.
- Equal at least 1 times the volume of flood storage lost below the 10-year and 100-year flood elevations;
- Be operational prior to placement of fill, structures, or other materials temporarily or permanently placed in the regulatory floodplain;
- Be provided in the immediate vicinity of the flood storage lost, where practical;
- Be provided in such a way to mimic as close as possible the function provided by the lost floodplain storage. If the floodplain storage is to be lost outside the active flow conveyance path, then it must be compensated for outside the flow conveyance path (e.g., a flood conveyance shelf/2-stage ditch, while improving conveyance and erosion, is not an appropriate compensation for floodplain storage lost in the floodway fringe area).
- Be provided in addition to the site retention/detention volume; and
- Drain freely and openly to the waterway.

Compensatory storage is also required to be provided incrementally such that:

- All floodplain storage/conveyance capacity lost within the floodway shall be compensated for within the floodway;
- All floodplain storage lost within the floodway fringe shall be compensated for within the floodway fringe;
- All floodplain storage lost below the existing 10-year flood elevation shall be compensated for below the proposed 10-year flood elevation; and
- All floodplain storage lost above the existing 10-year flood elevation shall be compensated for above the proposed 10-year flood elevation.

Note that compensatory storage is required for activities in the regulatory floodplain. There is no threshold to compensatory storage; any volume of fill requires compensatory storage be provided. However, the compensatory storage requirement does not apply to specific activities in the regulatory floodplain, such as the floodproofing of an existing building, where the floodproofing measures such as berms or floodwalls are within 10 feet of the building, or crossing improvements, where artificially created storage is lost due to a reduction in head loss.

Computing Compensatory Storage

Computations must show 1 times compensation for floodplain storage volume lost for 10-year and 100-year storm events. Storage lost between the existing ground and the existing 10-year flood elevation must be compensated by providing 1 time the amount lost and be placed between the existing ground elevation and the proposed 10-year floodplain elevation. Storage lost between the existing 10-year and the existing 100-year elevation must be compensated by providing 1 times the amount lost and be placed between the proposed 10-year and proposed 100-year elevation.

When preparing a grading plan, thought should be given to how compensatory storage will be quantified. The most common methodology is the use of cross sections and the "average end area method". The following requirements should be followed when preparing cross sections:

1. Prepare a detailed topographic survey tied to North American Vertical Datum of 1988 and any available City of Fishers Survey Control Network benchmarks.

2. Locate cross sections parallel to each other and perpendicular to a reference line, often times a property line or fence line. Cross sections used in a hydraulic model are always perpendicular to flood flows, and not always parallel to each other. Therefore, these are often not suitable for computing flood fringe compensatory storage volumes.

3. Plot cross sections at a standard engineering scale so as to allow the reviewer to verify areas. Horizontal scale should be a maximum of 1"=50' and vertical scale should be a maximum of 1"=5', or as approved by the County.

4. Show existing grades, proposed grades, existing and proposed 10-year flood elevations, existing and proposed 100-year flood elevations, normal water level, a reference line, and floodway limits on the cross sections on the plans.

5. Locate cross sections no more than 150 feet apart, with a minimum of three cross sections per cut/fill area, or as necessary to accurately quantify cuts and fills.

6. Locate cross sections to pick up critical features such as berms, ditches, and existing and proposed structures.

7. Each cross section should be numbered or lettered and referenced on the plans.

This information is then utilized to compute the areas of cut and fill. A sample grading plan, a typical cross section, and associated compensatory storage calculations for the 10-year flood are provided on **Figures 10-1**, **Figure 10-2**, and **Table 10-1**, respectively.

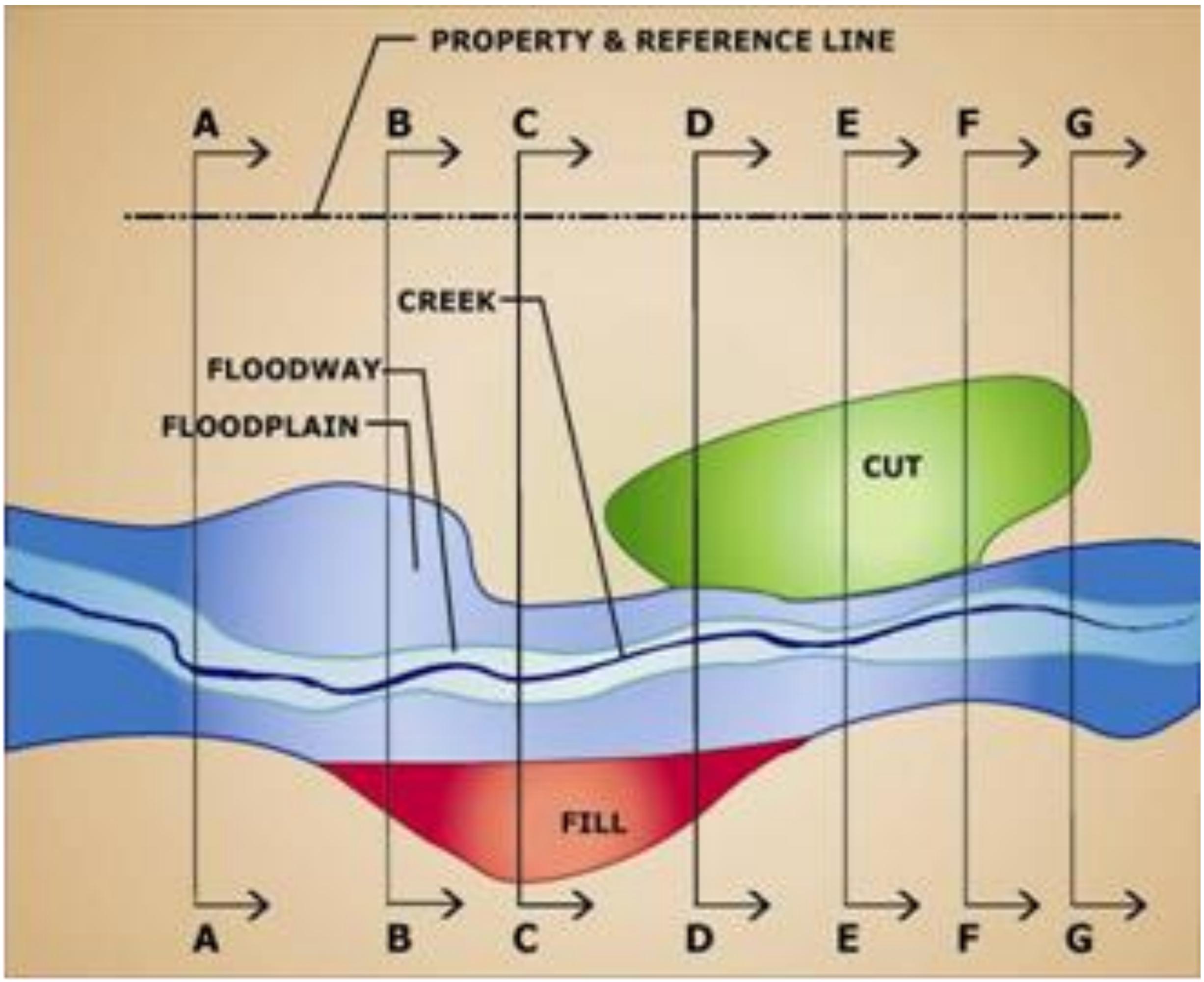
Volume of Fill between cross sections are calculated by finding the average fill cross sectional area and multiplying it by the distance between the two cross sections. For example, the fill volume between cross sections A and B is calculated as follows:

Average Fill Area = (Fill Area "A" + Fill Area "B")/2 = (0 ft^2 +100 ft^2)/2 = 50 ft^2
Volume of Fill = (Average Fill Area) × (Distance) = (50 ft^2) × (150 ft) = 7,500 ft^3

Once the total volume of fill placed, for this example, between the 0-and 10-yr flood elevations is determined, the total required compensatory storage can be calculated and compared against the total compensatory storage volume provided by the design as shown in the table. For this example:

Required Compensatory Storage = (1) × (Total Volume of Fill) = (1) × (36,250 ft^3)
= 36,250 ft^3

Figure 10-1 - Example Compensatory Storage Grading Plan



* Not to Scale & Topography not shown for clarity.

Figure 10-2 – Example Cross Section D-D

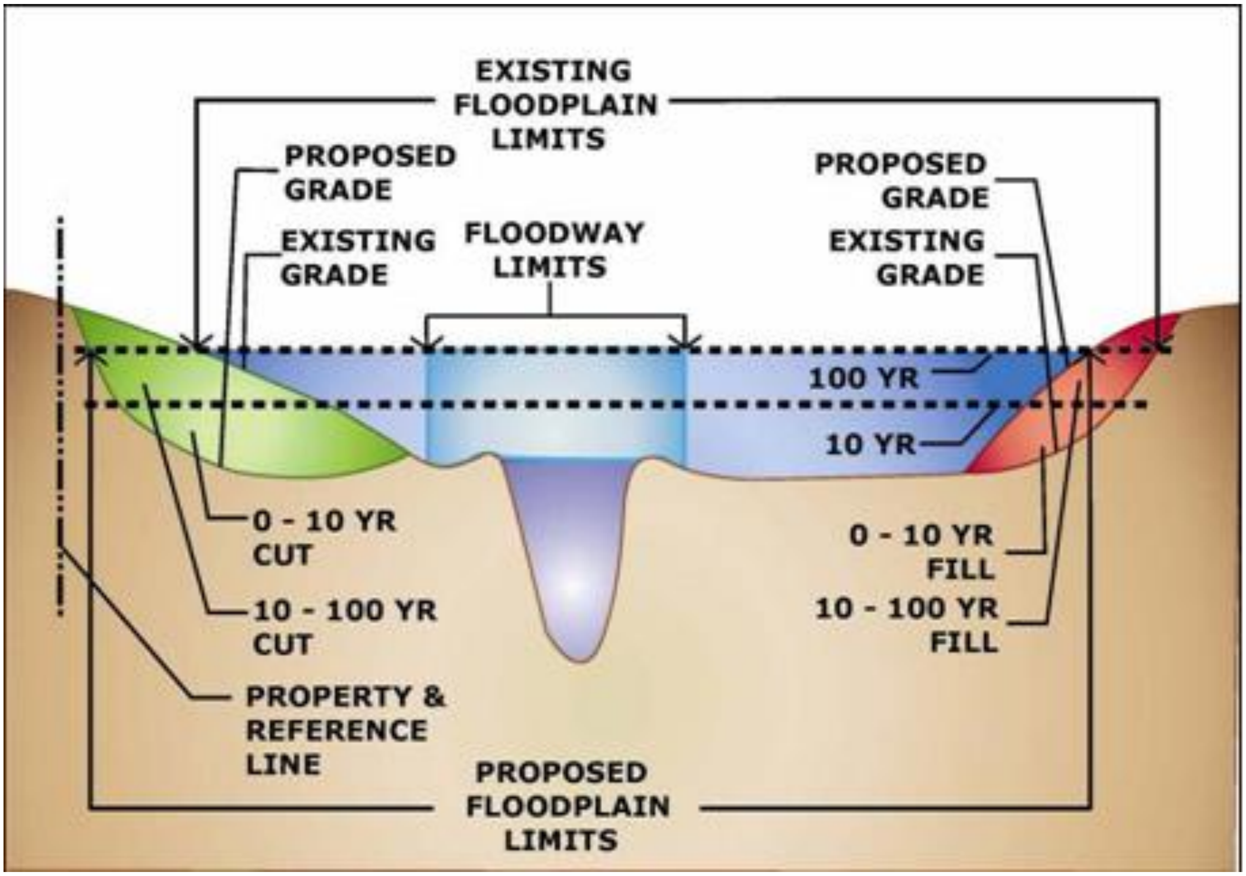


Table 1 - Example Compensatory Storage Calculations for 0-10 year event

Cross Section	Distance Between Sections (ft.)	Fill Area (sq. ft.)	Average Fill Area (sq. ft.)	Volume of Fill (cu. Ft.)	Cut Area (sq. ft.)	Average Cut (sq. ft.)	Volume of Cut (cu. Ft.)
A		0			0		
	150		50	7,500		0	
B		100			0		
	90		125	11,250		20	1,800
C		150			40		
	100		125	12,500		65	6,500
D		100			90		
	100		50	5,000		100	10,000
E		0			110		
	100		0	0		120	12,000
F		0			130		
	85		0	0		85	7,225
G		0			40		
Total Fill				**36,250**	Total Cut		**37,525**

Since the total amount of cut provided (37,525 ft^3 as shown in the table) is larger than that required (36,250 ft^3), the design meets the compensatory storage requirement for the 10-year flood. An additional table and calculation should be completed for the 100-year flood elevation in a similar manner to determine whether the design meets the compensatory storage requirement for the 100-year flood.

Location of Compensatory Storage

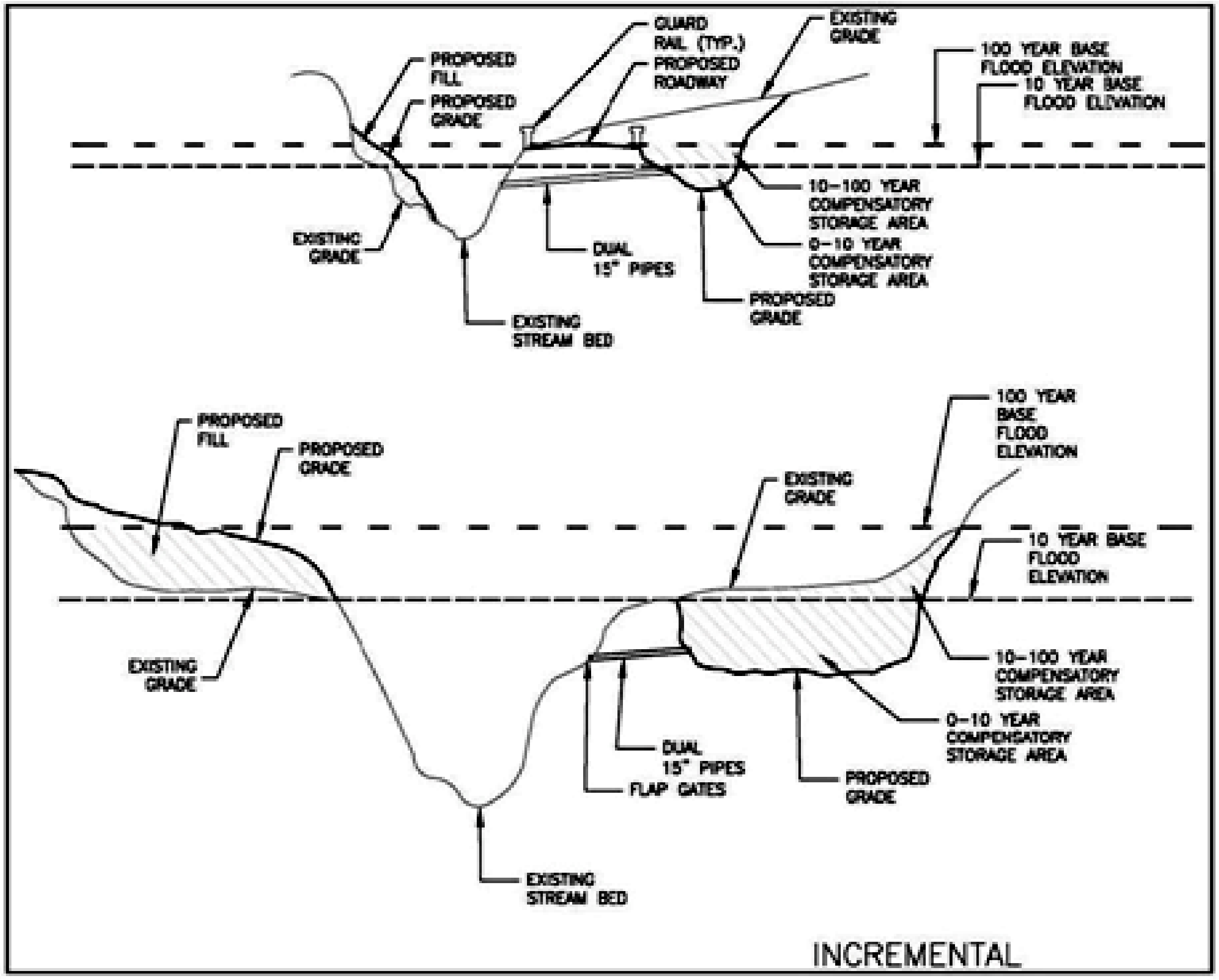
Compensatory storage must be located on-site and adjacent to or opposite the areas filled or occupied by a structure. In those rare instances when compensatory storage cannot be located adjacent to or opposite to the areas filled or occupied, engineering computations demonstrating that hydraulically equivalent compensatory storage has been provided is required. These computations must show that no increase in flood flows or flood depths will result as a result of the location of the proposed compensatory storage.

Compensatory storage must be constructed to drain freely and openly to watercourses. In some rare cases it may be necessary to install pipes to construct and/or operate a compensatory storage basin. This may occur when site constraints, such as a roadway or sidewalk, separate the waterway from the compensatory storage area. This is illustrated in the top half of **Figure 10-3**.

Another scenario may occur when a site cannot meet the incremental storage requirements discussed in this document. If incremental storage requirements from the 10-year to 100-year elevations cannot be met, pipes could be installed with a flap gate to prevent the water from entering from the stream bed at lower elevations. The berm could then be set at the elevation of the 10-year flood elevation, thus allowing the storage to only become effective above the 10-year flood elevation. This is illustrated in the bottom half of the illustration in Figure 10-3.

The use of pipes in compensatory storage will require approval by the County. If approved, two pipes will be required to reduce the risk of clogging. Pipes must be a minimum of 15 inches in diameter so as to allow water to enter and exit freely with a minimum head differential. If the compensatory storage is proposed to be combined with detention, it must be demonstrated the compensatory storage and detention do not interfere with one another.

Figure 10-3 – Example of Compensatory Storage Connection to Stream through Pipe



Compensatory Storage in the Regulatory Floodway

Only fill associated with appropriate uses of the regulatory floodway will be allowed to fill within the limits of the floodway. When, in rare circumstances, fill is allowed, all provisions discussed above relating to compensatory storage must be met in addition to the items discussed below.

- Any fill placed within the existing floodway must be compensated for within the proposed floodway.
- All floodway storage lost below the existing 10-year base flood elevation shall be replaced below the proposed 10-year base flood elevation.
- All floodway storage lost between the existing 10-year flood elevation and the existing 100-year flood elevation shall be replaced between the proposed 10-year and proposed 100-year flood elevation.

There shall be no reduction in floodway surface area as a result of a floodway modification, unless such modification is necessary to reduce flooding at an existing structure.

E. POLICY ON DAMS AND LEVEES

Dams and levees have the potential for significant, sometimes catastrophic consequences should they fail. In order to minimize the potential for loss of life and public safety, decrease the potential for increased flood damage and disaster costs, and safeguard the downstream property rights, the following shall be required by the City for any proposed new or improvements to any existing dam or levee. These requirements are in addition to what is normally required for other development subject to the Resolution or these Technical Standards and/or that required by State or Federal agencies.

1. Design of dams shall follow the requirements of the latest edition of IDNR-Division of Water "General Guidelines for New Dams and Improvements to Existing Dams in Indiana" as well as principles provided in the latest edition of "Indiana Dam Safety Inspection Manual".

2. Design of levee/floodwalls shall follow the FEMA requirements and guidelines provided in 44 CFR Section 65.10 and USACE Engineer Manual 1110-2-193, Design and Construction of Levees.

3. An Emergency Action Plan (EAP), including a detailed dam breach inundation map, shall be developed in accordance with the template provided in the latest edition of "Indiana Dam Safety Inspection Manual" and submitted to the City. The detailed dam breach inundation map referenced in this paragraph shall be developed for both "Sunny Day Breach" Scenario (breach during normal loading conditions) and for maximum loading condition with breach assumed to occur as the spillway system is passing the Spillway Design Flood associated with the dam ("SDF + Breach" Scenario).

4. Unless the "Sunny Day Breach Inundation Area" is entirely contained within the applicant's property and/ or contained within the existing 1% annual chance (100-year) floodplain, a copy of recorded flood/inundation easement or a recorded written consent for every property within the potential "Sunny Day Breach Inundation Area" shall be submitted to the City. In addition, all the affected property owners whose properties are located within the "SDF + Breach Inundation Area" must be notified of a hearing relevant to the proposed added risk. Notification of the time and place of the hearing shall be made in person or by certified mail at least five (5) to ten (10) days prior to the hearing. Proof of notice to each landowner shall be filed by affidavit with the City prior to the hearing.

5. A copy of a Management and Maintenance Plan for the proposed dam or levee developed in accordance with the latest edition of "Indiana Dam Safety Inspection Manual" shall be submitted to the City.

6. Unless a dam is subject to and regulated by the IDNR, following the permitting and construction of the dam or levee, a copy of a formal periodic inspection report prepared in accordance with the recommendations contained in the latest edition of “Indiana Dam Safety Inspection Manual” shall be submitted to the City along with evidence that the identified maintenance deficiencies have been corrected. The inspection report has to be submitted as it gets completed in accordance with the inspection frequency recommended in the latest edition of “Indiana Dam Safety Inspection Manual”.

F. REQUIREMENTS ASSOCIATED WITH PROPOSED DEVELOPMENTS DOWNSTREAM OF DAMS

As indicated in the previous section, dams have the potential for significant, sometimes catastrophic consequences should they fail. Placing new development downstream of an existing dam does not only expose the future residents or users of the newly developed areas to a potential new significant risk, but could also have an impact on the hazard rating of the dam itself, which can in turn make the dam non-compliant with the state and federal standards. In order to minimize the potential for loss of life and public safety, decrease the potential for increased flood damage and disaster costs, and safeguard the upstream dam owner’s rights, the following shall be required by the City for any proposed new development or redevelopment downstream of an existing dam. These requirements are in addition to what is normally required for new development or redevelopment subject to these Standards.

1. Dam breach inundation maps have been created for several existing dams within the State of Indiana by the dam owners, IDNR, or others as part of development of individual IEAPs for these dams. When the development location is suspected by the applicant or the City to be within an existing dam’s breach inundation zone, the applicant is required to include a copy of the breach inundation mapping associated with that dam as part of its development permit application. To locate such a mapping, the applicant should contact the dam owner, IDNR- Division of Water, the City, or other agencies to obtain the breach inundation map for the dam, if available. If no dam breach inundation map can be located for the dam, it will be the applicant’s responsibility to produce a City-acceptable dam breach mapping either through directly contracting with a qualified engineer or through funding the production of such a map by the City review consultant in accordance with standards and guidelines established by the IDNR-Division of Water.

2. If the location of the proposed development falls within the dam breach inundation zone on the map discussed under Item 1 (above), additional requirements as determined by the City may be imposed before a permit is issued and the development is allowed to occur. The noted additional requirements depend on several variables and are expected to vary case by case. Typical requirements could include relocating a portion or all of the proposed development to areas outside of the dam breach inundation zone, cost-sharing with the dam owner in necessary

upgrades to the dam as a result of a potential hazard classification increase, addition of structural protection measures (such as flood protection levees), additional freeboard requirements, development and periodic exercise of warning and evacuation plans, and other measures considered necessary by the City to minimize the potential for loss of life and public safety, decrease the potential for increased flood damage and disaster costs, and safeguard the upstream dam owner's rights.

G. DRAINAGE EASEMENT REQUIREMENTS

1. Minimum easement widths for storm drains shall be as provided below. More stringent requirements for stormwater easement size and additional covenants may be made by the City based upon individual site conditions.

Depth of Drain from Finish Grade to Crown	Diameter of Storm Drain	Maintain Easement Width
3 feet or less	15" or less	15 feet
More than 3 feet	15" or less	20 feet
3 feet or less	Greater than 15"	20 feet
More than 3 feet	Greater than 15"	25 feet

2. A minimum of 25 feet from top of the bank on each side of a new channel shall be designated on the recorded plat as a Drainage Easement. If the top of bank is not vegetated according the development's landscape plan, a minimum 25-foot width of filter strip shall be installed within the drainage easement.

3. Rear-yard swales, 100-year overflow paths, and emergency overflow routes associated with detention ponds shall be contained within a minimum of 30 feet width (15 feet from centerline on each side) of drainage easement.

4. A minimum of 30 feet beyond the actual footprint (top of the bank) of stormwater detention facilities shall be designated as drainage easement. A minimum 25-foot width easement shall also be required as access easement from a public right-of-way to the facility, unless the pond is immediately next to a public right-of-way.

APPENDIX A

ABBREVIATIONS AND DEFINITIONS

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ABBREVIATIONS AND DEFINITIONS

ABBREVIATIONS

BFE	Base Flood Elevation
BMP	Best Management Practice
CFS	Cubic Feet Per Second
CLOMR	Conditional Letter of Map Revision (from FEMA)
CLOMR-F	Conditional Letter of Map Revision Based on Fill (from FEMA)
CN	Curve Number
COE	United States Army Corps of Engineers
CSMP	Comprehensive Stormwater Management Program
CSO	Combined Sewer Overflow
CWA	Clean Water Act
ERM	Elevation Reference Mark
E&SC	Erosion and Sediment Control
EPA	Environmental Protection Agency
ETJ	Extraterritorial Jurisdiction
FBFM	Flood Boundary and Floodway Map
FEMA	Federal Emergency Management Agency
FHBM	Flood Hazard Boundary Map
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
FPG	Flood Protection Grade
FPS	Feet Per Second
GIS	Geographical Information System
GPS	Global Positioning System
HGL	Hydraulic Grade Line
HHW	Household Hazardous Waste

HUC	Hydrologic Unit Code
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
INDOT	Indiana Department of Transportation.
LAG	Lowest Adjacent Grade
LID	Low Impact Development
LOMA	Letter of Map Amendment (from FEMA)
LOMR	Letter of Map Revision (from FEMA)
LOMR-F	Letter of Map Revision Based on Fill (from FEMA)
MCM	Minimum Control Measure
MS4	Municipal Separate Storm Sewer System
NAVD	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NGVD 1929	National Geodetic Vertical Datum of 1929
NRCS	USDA-Natural Resources Conservation Service
NPDES	National Pollution Discharge Elimination System
NPS	Non-point source
POTW	Publicly Owned Treatment Works
SFHA	Special Flood Hazard Area
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
SWQMP	Stormwater Quality Management Plan
Tc	Time of Concentration
TMDL	Total Maximum Daily Load
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

DEFINITIONS

Acre-Foot (AF). A measure of water volume equal to the inundation of a flat one-acre area to a dept of one foot (43,560 cubic feet).

Administering authority. The designated unit of government given the authority to issue permits.

Agricultural land disturbing activity. Tillage, planting, cultivation, or harvesting operations for the production of agricultural or nursery vegetative crops. The term also includes pasture renovation and establishment, the construction of agricultural conservation practices, and the installation and maintenance of agricultural drainage tile. For purposes of this rule, the term does not include land disturbing activities for the construction of agricultural related facilities, such as barns, buildings to house livestock, roads associated with infrastructure, agricultural waste lagoons and facilities, lakes and ponds, wetlands; and other infrastructure.

Agricultural land use conservation practices. Use of land for the production of animal or plant life, including forestry, pasturing or yarding of livestock, and planting, growing, cultivating, and harvesting crops for human or livestock consumption. Practices that are constructed on agricultural land for the purposes of controlling soil erosion and sedimentation. These practices include grass waterways, sediment basins, terraces, and grade stabilization structures.

Amortization Period. The length of time used to repay a debt or mortgage or to depreciate an initial cost.

Antecedent Runoff Condition. The index of runoff potential before a storm event. The index, developed by the Soil Conservation Service (SCS), is an attempt to account for the variation of the SCS runoff curve number (CN) from storm to storm.

Backflow Preventer. Device that allows liquids to flow in only one direction in a pipe. Backflow preventers are used on sewer pipes to prevent a reverse flow during flooding situations.

Backwater. The rise in water surface elevation caused by some obstruction such as a narrow bridge opening, buildings or fill material that limits the area through which the water shall flow.

Base Flood Elevation. The water surface elevation corresponding to a flood having a one percent probability of being equaled or exceeded in a given year.

Base Flood. See "Regulatory Flood".

Base Flow. Stream discharge derived from groundwater sources as differentiated from surface runoff. Sometimes considered to include flows from regulated lakes or reservoirs.

Basement. A building story that is all or partly underground but having at least one-half of its height below the average level of the adjoining ground. A basement shall not be counted as a story for the purpose of height regulations.

Benchmark. A marked point of known elevation from which other elevations may be established.

Best Management Practices. Design, construction, and maintenance practices and criteria for stormwater facilities that minimize the impact of stormwater runoff rates and volumes, prevent erosion, and capture pollutants.

Buffer Strip. An existing, variable width strip of vegetated land intended to protect water quality and habitat.

Building. See “structure”.

Capacity of a Storm Drainage Facility. The maximum flow that can be conveyed or stored by a storm drainage facility without causing damage to public or private property.

Catch Basin. A chamber usually built at the curb line of a street for the admission of surface water to a storm drain or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

Centerline of Channel. The thalweg of a channel.

Channel Improvement. Alteration, maintenance, or reconstruction of the channel area for the purpose of improving the channel capacity or overall drainage efficiency. The noted "improvement" does not necessarily imply water quality or habitat improvement within the channel or its adjacent area.

Channel Modification. Alteration of a channel by changing the physical dimensions or materials of its bed or banks. Channel modification includes damming, rip-rapping or other armoring, widening, deepening, straightening, relocating, lining, and significant removal of bottom or woody vegetation. Channel modification does not include the clearing of dead or dying vegetation, debris, or trash from the channel. Channelization is a severe form of channel modification typically involving relocation of the existing channel (e.g., straightening).

Channel Stabilization. Protecting the sides and bed of a channel from erosion by controlling flow velocities and flow directions using jetties, drops, or other structures and/or by lining the channel with vegetation, riprap, concrete, or other suitable lining material.

Channel. A portion of a natural or artificial watercourse which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a defined bed and banks which serve to confine the water.

Class V injection well. A type of well, which typically has a depth greater than its largest surface dimension, emplaces fluids into the subsurface, and does not meet the definitions of Class I through Class IV wells as defined under 40 CFR 146.5. While the term includes the specific examples described in 40 CFR 144.81, septic systems that serve more than one (1) single-family dwelling or provide service for non-domestic waste, dug wells, bored wells, improved sinkholes, french drains, infiltration sumps, and infiltration galleries, it does not include surface impoundments, trenches, or ditches that are wider than they are deep.

Closed Conduit. A pipe, tube, or tile used for transmitting water.

Combined Sewer Overflow. A system designed and used to receive and transport combined sewage so that during dry periods the wastewater is carried to a treatment facility. During storm events, the excess water is discharged directly into a river, stream, or lake without treatment.

Compensatory Storage. An artificial volume of storage within a floodplain used to balance the loss of natural flood storage capacity when artificial fill or substructures are placed within the floodplain.

Compost. Organic residue (or a mixture of organic residue and soil) that has undergone biological decomposition until it has become relatively stable humus.

Comprehensive Stormwater Management Program. A comprehensive stormwater program for effective management of stormwater quantity and quality throughout the community.

Constructed Wetland. A manmade shallow pool that creates growing conditions suitable for wetland vegetation and is designed to maximize pollutant removal.

Construction activity. Land disturbing activities associated with the construction of infrastructure and structures. This term does not include routine ditch or road maintenance or minor landscaping projects.

Construction plan. A representation of a project site and all activities associated with the project. The plan includes the location of the project site, buildings and other infrastructure, grading activities, schedules for implementation and other pertinent information related to the project site. A storm water pollution prevention plan is a part of the construction plan.

Construction site access. A stabilized stone surface at all points of ingress or egress to a project site, for the purpose of capturing and detaining sediment carried by tires of vehicles or other equipment entering or exiting the project site.

Contiguous. Adjoining or in actual contact with.

Contour Line. Line on a map which represents a contour or points of equal elevation.

Contour. An imaginary line on the surface of the earth connecting points of the same elevation.

Contractor or subcontractor. An individual or company hired by the project site or individual lot owner, their agent, or the individual lot operator to perform services on the project site.

Control Structure. A structure designed to control the rate of flow that passes through the structure, given a specific upstream and downstream water surface elevation.

Conveyance. Any structural method for transferring stormwater between at least two points. The term includes piping, ditches, swales, curbs, gutters, catch basins, channels, storm drains, and roadways.

Convolution. The process of translating precipitation excess into a runoff hydrograph.

Crawl Space. Low space below first floor of a house where there has not been excavation deep enough for a basement, usually less than seven (7) feet in depth, but where there is access for pipes, ducts, utilities and similar equipment.

Critical Duration Analysis. The process of testing different rainfall durations to find that “critical duration”, which produces the highest peak runoff or the highest storage volume.

Cross-Section. A graph or plot of ground elevation across a stream valley or a portion of it, usually along a line perpendicular to the stream or direction of flow.

Crown of Pipe. The elevation of top of pipe.

Cubic Feet Per Second (CFS). Used to describe the amount of flow passing a given point in a stream channel. One cubic foot per second is equivalent to approximately 7.5 gallons per second.

Culvert. A closed conduit used for the conveyance of surface drainage water under a roadway, railroad, canal or other impediment.

Curve Number (CN). The Soil Conservation Service index that represents the combined hydrologic effect of soil, land use, land cover, hydrologic condition and antecedent runoff condition.

Dam. A barrier to confine or impound water for storage or diversion, to prevent gully erosion, or to retain soil, sediment, or other debris.

Damage. Measurable rise in flood heights on buildings currently subject to flooding, flooding of buildings currently not subject to flooding and increases in volume or velocity to the point where the rate of land lost to erosion and scour is substantially increased.

Datum. Any level surface to which elevations are referred, usually Mean Sea Level.

Dechlorinated swimming pool discharge. Chlorinated water that has either sat idle for seven (7) days following chlorination prior to discharge to the MS4 conveyance, or, by analysis, does not contain detectable concentrations (less than five-hundredths (0.05) milligram per liter) of chlorinated residual.

Depressional Storage Areas. Non-riverine depressions in the earth where stormwater collects. The volumes are often referred to in units of acre-feet.

Design Storm. A selected storm event, described in terms of the probability of occurring once within a given number of years, for which drainage or flood control improvements are designed and built.

Detention Basin. A facility constructed or modified to restrict the flow of storm water to a prescribed maximum rate, and to detain concurrently the excess waters that accumulate behind the outlet.

Detention Facility. A facility designed to detain a specified amount of stormwater runoff assuming a specified release rate. The volumes are often referred to in units of acre-feet.

Detention Storage. The temporary detaining of stormwater in storage facilities, on rooftops, in streets, parking lots, school yards, parks, open spaces or other areas under predetermined and controlled conditions, with the rate of release regulated by appropriately installed devices.

Detention Time. The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

Detention. Managing stormwater runoff by temporary holding and controlled release.

Detritus. Dead or decaying organic matter; generally contributed to stormwater as fallen leaves and sticks or as dead aquatic organisms.

Developer. Any person financially responsible for construction activity, or an owner of property who sells or leases, or offers for sale or lease, any lots in a subdivision.

Development. Any man-made change to improved or unimproved real estate including but not limited to:

1. Construction, reconstruction, or placement of a building or any addition to a building;
2. Construction of flood control structures such as levees, dikes, dams or channel improvements;
3. Construction or reconstruction of bridges or culverts;
4. Installing a manufactured home on a site, preparing a site for a manufactured home, or installing a recreational vehicle on a site for more than hundred eight (180) days;
5. Installing utilities, erection of walls, construction of roads, or similar projects;
6. Mining, dredging, filling, grading, excavation, or drilling operations;
7. Storage of materials; or
8. Any other activity that might change the direction, height, or velocity of flood or surface waters.

"Development" does not include activities such as the maintenance of existing buildings and facilities such as painting, re-roofing, resurfacing roads, or gardening, plowing and similar agricultural practices that do not involve filling, grading, excavation, or the construction of permanent buildings.

Direct Release. A method of stormwater management where runoff from a part or the entire development is released directly to the receiving stream without providing detention.

Discharge. Usually the rate of water flow. A volume of fluid passing a point per unit time commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, or millions of gallons per day.

Disposal. The discharge, deposit, injection, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that the solid waste or hazardous waste, or any constituent of the waste, may enter the environment, be emitted into the air, or be discharged into any waters, including

Ditch. A man-made, open drainageway in or into which excess surface water or groundwater drained from land, stormwater runoff, or floodwaters flow either continuously or intermittently.

Drain. A buried slotted or perforated pipe or other conduit (subsurface drain) or a ditch (open drain) for carrying off surplus groundwater or surface water.

Drainage Area. The area draining into a stream at a given point. It may be of different sizes for surface runoff, subsurface flow and base flow, but generally the surface runoff area is considered as the drainage area.

Drainage Classification (soil). As a natural condition of the soil, drainage refers to both the frequency and duration of periods when the soil is free of saturation. Soil drainage conditions are defined as:

- *Well-drained*--Excess water drains away rapidly, and no mottling occurs within 36 in. of the surface.
- *Moderately well drained*--Water is removed from the soil somewhat slowly resulting in small but significant periods of wetness, and mottling occurs between 18 and 36 in.
- *Somewhat poorly drained*--Water is removed from the soil slowly enough to keep it wet for significant periods but not all of the time, and mottling occurs between 8 to 18 in.

- *Poorly drained*--Water is removed so slowly that it is wet for a large part of the time, and mottling occurs between 0 and 8 in.
- *Very poorly drained*--Water is removed so slowly that the water table remains at or near the surface for the greater part of the time; there may also be periods of surface ponding; the soil has a black to gray surface layer with mottles up to the surface.

Drainage. The removal of excess surface water or groundwater from land by means of ditches or subsurface drains. Also see Natural drainage.

Drop Manhole. Manhole having a vertical drop pipe connecting the inlet pipe to the outlet pipe. The vertical drop pipe shall be located immediately outside the manhole.

Dry Well. A type of infiltration practice that allows stormwater runoff to flow directly into the ground via a bored or otherwise excavated opening in the ground surface.

Dry-Bottom Detention Basin. A basin designed to be completely dewatered after having provided its planned detention of runoff during a storm event.

Duration. The time period of a rainfall event.

Earth Embankment. A man-made deposit of soil, rock, or other material often used to form an impoundment.

Elevation Certificate. A form published by the Federal Emergency Management Agency that is used to certify the 100-year or base flood elevation and the lowest elevation of usable space to which a building has been constructed.

Elevation Reference Mark (ERM). Elevation benchmark tied to the National Geodetic Vertical Datum of 1929 and identified during the preparation of a Flood Insurance Study prepared for the Federal Emergency Management Agency.

Emergency Spillway. Usually a vegetated earth channel used to safely convey flood discharges around an impoundment structure.

Energy Dissipater. A device to reduce the energy of flowing water.

Environment. The sum total of all the external conditions that may act upon a living organism or community to influence its development or existence.

Erosion and sediment control measure. A practice, or a combination of practices, to control erosion and resulting sedimentation. and/or off-site damages.

Erosion and sediment control system. The use of appropriate erosion and sediment control measures to minimize sedimentation by first reducing or eliminating erosion at the source and then as necessary, trapping sediment to prevent it from being discharged from or within a project site.

Erosion control plan. A written description and site plan of pertinent information concerning erosion control measures designed to meet the requirements of the Resolution.

Erosion. The wearing away of the land surface by water, wind, ice, gravity, or other geological agents. The following terms are used to describe different types of water erosion:

- *Accelerated erosion*--Erosion much more rapid than normal or geologic erosion, primarily as a result of the activities of man.
- *Channel erosion* --An erosion process whereby the volume and velocity of flow wears away the bed and/or banks of a well-defined channel.
- *Gully erosion* --An erosion process whereby runoff water accumulates in narrow channels and, over relatively short periods, removes the soil to considerable depths, ranging from 1-2 ft. to as much as 75-100 ft.
- *Rill erosion*--An erosion process in which numerous small channels only several inches deep are formed; occurs mainly on recently disturbed and exposed soils (see Rill).
- *Splash erosion*--The spattering of small soil particles caused by the impact of raindrops on wet soils; the loosened and spattered particles may or may not be subsequently removed by surface runoff.
- *Sheet erosion*--The gradual removal of a fairly uniform layer of soil from the land surface by runoff water.

Extraterritorial Jurisdiction (ETJ). Areas located outside the corporate limits of a community over which the community has statutory development authority.

Farm or Field Tile. A pipe installed in an agricultural area to allow subsurface drainage of farmland for the purpose of agricultural production.

FEMA. The Federal Emergency Management Agency.

Filter Strip. Usually a long, relatively narrow area (usually, 20-75 feet wide) of undisturbed or planted vegetation used near disturbed or impervious surfaces to filter stormwater pollutants for the protection of watercourses, reservoirs, or adjacent properties.

Final stabilization. The establishment of permanent vegetative cover or the application of a permanent nonerosive material to areas where all land disturbing activities have been completed and no additional land disturbing activities are planned under the current permit.

Floatable. Any solid waste that will float on the surface of the water.

Flood (or Flood Waters). A general and temporary condition of partial or complete inundation of normally dry land areas from the overflow, the unusual and rapid accumulation, or the runoff of surface waters from any source.

Flood Boundary and Floodway Map (FBFM). A map prepared by the Federal Emergency Management Agency the depicts the FEMA designated floodways within a community. This map also includes delineation of the 100-year and 500-year floodplain boundaries and the location of the Flood Insurance Study cross-sections.

Flood Crest. The maximum stage or elevation reached or expected to be reached by the waters of a specific flood at a given time.

Flood Duration. The length of time a stream is above flood stage or overflowing its banks.

Flood Easement. Easement granted to identify areas inundated by the 100-year flood and prohibit or severely restrict development activities.

Flood Elevation. The elevation at all locations delineating the maximum level of high waters for a flood of given return period.

Flood Fighting. Actions taken immediately before or during a flood to protect human life and to reduce flood damages such as evacuation, emergency sandbagging and diking.

Flood Forecasting. The process of predicting the occurrence, magnitude and duration of an imminent flood through meteorological and hydrological observations and analysis.

Flood Frequency. A statistical expression of the average time period between floods equaling or exceeding a given magnitude. For example, a 100-year flood has a magnitude expected to be equaled or exceeded on the average of once every hundred years; such a flood has a one-percent chance of being equaled or exceeded in any given year. Often used interchangeably with "recurrence interval".

Flood Hazard Area. Any floodplain, floodway, floodway fringe, or any combination thereof which is subject to inundation by the regulatory flood; or any flood plain as delineated by Zone A on a Flood Hazard Boundary Map.

Flood Hazard Boundary Map (FHBM). A map prepared by the Federal Emergency Management Agency that depicts Special Flood Hazard Areas as a Zone A within a community. There are no study text, base flood elevations, or floodways associated with this map.

Flood Insurance Rate Map (FIRM). A map prepared by the Federal Emergency Management Agency that depicts Special Flood Hazard Areas within a community. This map also includes the 100-year or Base Flood Elevation at various locations along the watercourses. More recent versions of the FIMR may also show the FEMA designated floodway boundaries and the location of the Flood Insurance Study cross-sections.

Flood Insurance Study (FIS). A study prepared by the Federal Emergency Management agency to assist a community participating in the National Flood Insurance Program in its application of the program regulations. The study consists of a text which contains community background information with respect to flooding, a floodway data table, summary of flood discharges, flood profiles, a Flood Insurance Rate Map, and a Flood Boundary and Floodway Map.

Flood Profile. A graph showing the relationship of water surface elevation to a specific location, the latter generally expressed as distance above the mouth of a stream of water flowing in a channel. It is generally drawn to show surface elevation for the crest or a specific magnitude of flooding, but may be prepared for conditions at any given time or stage.

Flood Protection Grade (FPG). The elevation of the regulatory or 100-year flood plus two (2) feet at any given location in the Special Flood Hazard Area or 100-year floodplain.

Flood Protection Grade. The elevation of the lowest floor of a building, including the basement, which shall be two feet above the elevation of the regulatory flood.

Flood Resistant Construction (Flood Proofing). Additions, changes or adjustments to structures or property that are designed to reduce or eliminate the potential for flood damage.

Flood Storage Areas. Depressions, basins, or other areas that normally stand empty or partially empty, but fill with rainfall runoff during storms to hold the runoff and reduce downstream flow rates. The volumes are often referred to in units or acre-feet.

Floodplain Management. The operation of a program of corrective and preventive measures for reducing flood damage, including but not limited to flood control projects, floodplain land use regulations, flood proofing of buildings, and emergency preparedness plans.

Floodplain Regulations. General term applied to the full range of codes, ordinances and other regulations relating to the use of land and construction within floodplain limits. The term encompasses zoning ordinances, subdivision regulations, building and housing codes, encroachment laws and open area (space) regulations.

Floodplain. The channel proper and the areas adjoining the channel which have been or hereafter may be covered by the regulatory or 100-year flood. Any normally dry land area that is susceptible to being inundated by water from any natural source. The floodplain includes both the floodway and the floodway fringe districts.

Floodway Fringe. That portion of the flood plain lying outside the floodway, which is inundated by the regulatory flood.

Floodway. The channel of a river or stream and those portions of the floodplains adjoining the channel which are reasonably required to efficiently carry and discharge the peak flow of the regulatory flood of any river or stream.

Footing Drain. A drain pipe installed around the exterior of a basement wall foundation to relieve water pressure caused by high groundwater elevation.

Forebay (or Sediment Forebay). A small pond placed in front of a larger retention/detention structure such as a wet pond, dry pond, or wetland to intercept and concentrate a majority of sediment that is coming into the system before it reaches the larger structure.

Freeboard. An increment of height added to the base flood elevation to provide a factor of safety for uncertainties in calculations, unknown local conditions, wave actions and unpredictable effects such as those caused by ice or debris jams. (See Flood Protection Grade).

French Drain. A drainage trench backfilled with a coarse, water-transmitting material; may contain a perforated pipe.

Gabion. An erosion control structure consisting of a wire cage or cages filled with rocks.

Gaging Station. A selected section of a stream channel equipped with a gage, stage recorder, or other facilities for determining stream stage and discharge.

Garbage. All putrescible animal solid, vegetable solid, and semisolid wastes resulting from the processing, handling, preparation, cooking, serving, or consumption of food or food materials.

Geographical Information System. A computer system capable of assembling, storing, manipulation, and displaying geographically referenced information. This technology can be used for resource management and development planning.

Geotextile Fabric. A woven or non-woven, water-permeable synthetic material used to trap sediment particles, prevent the clogging of aggregates with fine grained soil particles, or as a separator under road aggregate.

Geotextile Liner. A synthetic, impermeable fabric used to seal impoundments against leaks.

Global Positioning System. A system that provides specially coded satellite signals that is processed by a receiver, which determines position, velocity, and time. The system is funded and controlled by the U.S. Department of Defense.

Grade. (1) The inclination or slope of a channel, canal, conduit, etc., or natural ground surface usually expressed in terms of the percentage the vertical rise (or fall) bears to the corresponding horizontal distance. (2) The finished surface of a canal bed, roadbed, top of embankment, or bottom of excavation; any surface prepared to a design elevation for the support of construction, such as paving or the laying of a conduit. (3) To finish the surface of a canal bed, roadbed, top of embankment, or bottom of excavation, or other land area to a smooth, even condition.

Grading. The cutting and filling of the land surface to a desired slope or elevation.

Grass. A member of the botanical family Graminae, characterized by blade-like leaves that originate as a sheath wrapped around the stem.

Grassed Waterway. A natural or constructed waterway, usually broad and shallow, covered with erosion-resistant grasses and used to conduct surface water from an area.

Ground Cover (horticulture). Low-growing, spreading plants useful for low-maintenance landscape areas.

Groundwater Recharge. The infiltration of water into the earth. It may increase the total amount of water stored underground or only replenish supplies depleted through pumping or natural discharge.

Groundwater. Accumulation of underground water - natural or artificial. The term does not include man-made underground storage or conveyance structures.

Habitat. The environment in which the life needs of a plant or animal are supplied.

Hard Surface. See “Impervious Surface.”

High Water. Maximum designed permitted, or regulated water level for an impoundment.

Household Hazardous Waste. Solid waste generated by households that is ignitable, toxic, reactive, corrosive, or otherwise poses a threat to human health or the environment.

Hydraulic Grade Line (HGL). For channel flow, the HGL is equal to the water surface whereas for pressure flow it is the piezometric surface.

Hydraulics. A branch of science that deals with the practical application of the mechanics of water movement. A typical hydraulic study is undertaken to calculate water surface elevations.

Hydrodynamic Loads. Forces imposed on structures by floodwaters due to the impact of moving water on the upstream side of the structure, drag along its sides, and eddies or negative pressures on its downstream side.

Hydrograph. For a given point on a stream, drainage basin, or a lake, a graph showing either the discharge, stage (depth), velocity, or volume of water with respect to time.

Hydrologic Unit Code. A numeric United States Geologic Survey code that corresponds to a watershed area. Each area also has a text description associated with the numeric code.

Hydrology. The science of the behavior of water in the atmosphere, on the surface of the earth, and underground. A typical hydrologic study is undertaken to compute flow rates associated with specified flood events.

Hydrometeorologic. Water-related meteorological data such as rainfall or runoff.

Hydrostatic Loads. Those loads or pressures resulting from the static mass of water at any point of floodwater contact with a structure. They are equal in all direction and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors, decks and roofs, and can act laterally on upright structural members such as walls, piers, and foundations.

IDNR. Indiana Department of Natural Resources.

Illicit Discharge. Any discharge to a conveyance that is not composed entirely of stormwater except naturally occurring floatables, such as leaves or tree limbs.

Impact Areas. Areas defined or mapped that are unlikely to be easily drained because of one or more factors including but not limited to any of the following: soil type, topography, land where there is not adequate outlet, a floodway or floodplain, land within 75 feet of each bank of any regulated drain or within 75 feet from the centerline of any regulated tile ditch.

Impaired Waters. Waters that do not or are not expected to meet applicable water quality standards, as included on IDEM's CWA Section 303(d) List of Impaired Waters.

Impervious surface. Surfaces, such as pavement and rooftops, which prevent the infiltration of stormwater into the soil.

Individual building lot. A single parcel of land within a multi-parcel development.

Individual lot operator. A contractor or subcontractor working on an individual lot.

Individual lot owner. A person who has financial control of construction activities for an individual lot.

INDOT. Indiana Department of Transportation. Generally used here to refer to specifications contained in the publication "INDOT Standard Specifications."

Infiltration practices. Any structural BMP designed to facilitate the percolation of run-off through the soil to ground water. Examples include infiltration basins or trenches, dry wells, and porous pavement.

Infiltration. Passage or movement of water into the soil.

Infiltration Swales. A depressed earthen area that is designed to promote infiltration.

Inlet. An opening into a storm drain system for the entrance of surface storm water runoff, more completely described as a storm drain inlet.

Intermittent Stream. A stream which carries water a considerable portion of the time, but which ceases to flow occasionally or seasonally because bed seepage and evapotranspiration exceed the available water supply.

Invert. The inside bottom of a culvert or other conduit.

Junction Chamber. A converging section of conduit, usually large enough for a person to enter, used to facilitate the flow from one or more conduits into a main conduit.

Land Surveyor. A person licensed under the laws of the State of Indiana to practice land surveying.

Land-disturbing Activity. Any man-made change of the land surface, including removing vegetative cover that exposes the underlying soil, excavating, filling, transporting and grading.

Larger common plan of development or sale. A plan, undertaken by a single project site owner or a group of project site owners acting in concert, to offer lots for sale or lease; where such land is contiguous, or is known, designated, purchased or advertised as a common unit or by a common name, such land shall be presumed as being offered for sale or lease as part of a larger common plan. The term also includes phased or other construction activity by a single entity for its own use.

Lateral Storm Sewer. A drain that has inlets connected to it but has no other storm drain connected.

Life Cycle Cost. Cost based on the total cost incurred over the system life including research, development, testing, production, construction, operation, and maintenance. Costs are normally determined on present worth or equivalent annual cost basis.

Lowest Entry Elevation. The lowest elevation along the perimeter of a structure where overbank flooding can enter the structure.

Lowest Adjacent Grade. The elevation of the lowest grade adjacent to a structure, where the soil meets the foundation around the outside of the structure (including structural members such as basement walkout, patios, decks, porches, support posts or piers, and rim of the window well.

Low Impact Development. LID is a land planning and engineering design approach with a goal of replicating the pre-development hydrologic regime of urban and developing watersheds. The primary goal of LID is to mimic a site's predevelopment hydrology by reducing the impervious surface, infiltrating, filtering, storing, evaporating, and detaining runoff close to its source.

Major Drainage System. Drainage system carrying runoff from an area of one or more square miles.

Manhole. Storm drain structure through which a person may enter to gain access to an underground storm drain or enclosed structure.

Manning Roughness Coefficient or Manning's "n" Value. A dimensionless coefficient ("n") used in the Manning's equation to account for channel wall frictional losses in steady uniform flow.

Measurable storm event. A precipitation event that results in a total measured precipitation accumulation equal to, or greater than, one-half (0.5) inch of rainfall.

Minimum Control Measure. Minimum measures required by the NPDES Phase II program. The six (6) MCMs are: Public education and outreach, Public participation and involvement, Illicit discharge detection and elimination, Construction site runoff control, Post-construction runoff control, and Pollution prevention and good housekeeping.

Minor Drainage Systems. Drainage system carrying runoff from an area of less than one square mile.

Minor Subdivision. See Subdivision, Minor.

Mulch. A natural or artificial layer of plant residue or other materials covering the land surface which conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Multi-Family. Any structure which contains three or more dwelling units. A dwelling unit is any structure, or part of a structure, which is constructed to a house a family.

Municipal Separate Storm Sewer System. An MS4 meets all the following criteria: (1) is a conveyance or system of conveyances owned by the state, county, city, town, or other public entity; (2) discharges to waters of the U.S.; (3) is designed or used for collecting or conveying stormwater; (4) is not a combined sewer; and, (5) is not part of a Publicly Owned Treatment Works (POTW).

Municipal, state, federal, or institutional refueling area. An operating gasoline or diesel fueling area whose primary function is to provide fuel to either municipal, state, federal, or institutional equipment or vehicles.

Mutual Drain. A drain that: (1) Is located on two or more tracts of land that are under different ownership; (2) was established by the mutual consent of all the owners; and (3) was not established under or made subject to any drainage statute.

National Flood Insurance Program (NFIP). The NFIP is a Federal program enabling property owners to purchase flood insurance. The Federal Emergency Management Agency administers the NFIP in communities throughout the Unites States. The NFIP is based on an agreement between local communities and the Federal government which states that if a community will implement floodplain management measures to reduce future flood risks to new construction and substantially improved structures in flood hazard areas, the Federal government will make flood insurance available within the community as a financial protection against flood losses that do occur.

National Geodetic Vertical Datum of 1929. The nationwide, Federal Elevation datum used to reference topographic elevations to a known value.

National Pollution Discharge Elimination System (NPDES). A permit developed by the U.S. EPA through the Clean Water Act. In Indiana, the permitting process has been delegated to IDEM. This permit covers aspects of municipal stormwater quality.

Natural Drainage. The flow patterns of stormwater run-off over the land in its pre-development state.

Nonagricultural land use. Commercial use of land for the manufacturing and wholesale or retail sale of goods or services, residential or institutional use of land intended primarily to shelter people, highway use of land including lanes, alleys, and streets, and other land uses not included in agricultural land use.

Nonpoint Source Pollution. Pollution that enters a water body from diffuse origins on the watershed and does not result from discernable, confined, or discrete conveyances.

Normal Depth. Depth of flow in an open conduit during uniform flow for the given conditions.

North American Vertical Datum of 1988 (NAVD 1988). The nationwide, Federal Elevation datum used to reference topographic elevations to a known value.

Nutrient(s). (1) A substance necessary for the growth and reproduction of organisms. (2) In water, those substances (chiefly nitrates and phosphates) that promote growth of algae and bacteria.

Off-site. Everything not located at or within a particular site.

Off-site Land Areas. Those areas that by virtue of existing topography naturally shed surface water onto or through the developing property.

100-Year Frequency Flood. See "regulatory flood".

On-Site. Located within the controlled or urbanized area where runoff originates.

Open Drain. A natural watercourse or constructed open channel that conveys drainage water.

Open Space. Any land area devoid of any disturbed or impervious surfaces created by industrial, commercial, residential, agricultural, or other manmade activities.

Orifice. A device which controls the rate of flow from a detention basin.

Outfall scouring. The deterioration of a streambed or lakebed from an outfall discharge to an extent that the excessive settling of solid material results and suitable aquatic habitat is diminished.

Outfall. The point, location, or structure where a pipe or open drain discharges to a receiving body of water.

Outlet. The point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Overland Flow. Consists of sheet flow, shallow concentrated flow and channel flow.

Peak Discharge (or Peak Flow). The maximum instantaneous flow from a given storm condition at a specific location.

Percolation. The movement of water through soil.

Perennial Stream. A stream that maintains water in its channel throughout the year.

Permanent stabilization. The establishment, at a uniform density of seventy percent (70%) across the disturbed area, of vegetative cover or permanent non-erosive material that will ensure the resistance of the soil to erosion, sliding, or other movement.

Permeability (soil). The quality of a soil that enables water or air to move through it. Usually expressed in inches per hour or inches per day.

Pervious. Allowing movement of water.

Pesticides. Chemical compounds used for the control of undesirable plants, animals, or insects. The term includes insecticides, herbicides, algicides, rodenticides, nematicides, fungicides, and growth regulators.

pH. A numerical measure of hydrogen ion activity, the neutral point being 7.0. All pH values below 7.0 are acid, and all above 7.0 are alkaline.

Phasing of construction. Sequential development of smaller portions of a large project site, stabilizing each portion before beginning land disturbance on subsequent portions, to minimize exposure of disturbed land to erosion.

Phosphorus (available). Inorganic phosphorus that is readily available for plant growth.

Piping. The formation of "pipes" by underground erosion. Water in the soil carries the fine soil particles away, and a series of eroded tubes or tunnels develop. These openings will grow progressively larger and can cause a dam failure.

Planimetric Data. Horizontal measurements involving distances or dimensions on a diagram, map, Plat of Survey or topographic map. Normally in units of feet.

Plat of Survey. A scaled diagram showing boundaries of a tract of land or subdivision. This may constitute a legal description of the land and be used in lieu of a written description.

Point Source. Any discernible, confined, and discrete conveyance including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, or container from which pollutants are or maybe discharged (P.L. 92-500, Section 502[14]).

Pollutant of concern. Any pollutant that has been documented via analytical data as a cause of impairment in any waterbody.

Porosity. The volume of pore space in soil or rock.

Porous pavement. A type of infiltration practice to improve the quality and reduce the quantity of storm water run-off via the use of manmade, pervious pavement which allows run-off to percolate through the pavement and into underlying soils

Private Drain. A drain that: (1) Is located on land owned by one person or by two or more persons jointly; and (2) was not established under or made subject to any drainage statute.

Professional Engineer. A person licensed under the laws of the State of Indiana to practice professional engineering.

Programmatic Indicator. Any data collected by an MS4 entity that is used to indicate implementation of one (1) or more minimum control measures.

Project site owner. The person required to submit a stormwater permit application, and required to comply with the terms of the Resolution, including a developer or a person who has financial and operational control of construction activities, and project plans and specifications, including the ability to make modifications to those plans and specifications.

Project site. The entire area on which construction activity is to be performed.

Probable Maximum Flood. The most severe flood that may be expected from a combination of the most critical meteorological and hydrological conditions that are reasonably possible in the drainage basin. It is used in designing high-risk flood protection works and siting of structures and facilities that shall be subject to almost no risk of flooding. The probable maximum flood is usually much larger that the 100-year flood.

Publicly Owned Treatment Works (POTW). A municipal operation that breaks down and removes contaminants in the wastewater prior to discharging to a stream through primary and/or secondary treatment systems.

Qualified professional. An individual who is trained and experienced in storm water treatment techniques and related fields as may be demonstrated by state registration, professional certification, experience, or completion of coursework that enable the individual to make sound, professional judgments regarding storm water control or treatment and monitoring, pollutant fate and transport, and drainage planning.

Radius of Curvature. Length of radius of a circle used to define a curve.

Rain garden. A vegetative practice used to alter impervious surfaces, such as roofs, into pervious surfaces for absorption and treatment of rainfall.

Rainfall Intensity. The rate at which rain is falling at any given instant, usually expressed in inches per hour.

Reach. Any length of river, channel or storm drain.

Receiving Stream or Receiving Water. The body of water into which runoff or effluent is discharged. The term does not include private drains, unnamed conveyances, retention and detention basins, or constructed wetlands used as treatment.

Recharge. Replenishment of groundwater reservoirs by infiltration and transmission from the outcrop of an aquifer or from permeable soils.

Recurrence Interval. A statistical expression of the average time between floods equaling or exceeding a given magnitude.

Redevelopment. Alterations of a property that change a site or building in such a way that there is disturbances of one (1) acre or more of land. The term does not include such activities as exterior remodeling.

Regional Pond. A detention/retention basin sized to detain/retain the runoff from the entire watershed, on-site and off-site, tributary to the pond's outlet.

Regulated Area. The following areas within City of Fishers:

1. All territory of the City.

Regulated Drain. A drain subject to the provisions of the Indiana Drainage Code, I.C.-36-9-27.

Regulatory or 100-Year Flood. The discharge or elevation associated with the 100-year flood as calculated by a method and procedure which is acceptable to and approved by the Indiana Department of Natural Resources and the Federal Emergency Management Agency. The "regulatory flood" is also known as the "base flood".

Regulatory Floodway. See Floodway.

Release Rate - The amount of storm water release from a storm water control facility per unit of time.

Reservoir. A natural or artificially created pond, lake or other space used for storage, regulation or control of water. May be either permanent or temporary. The term is also used in the hydrologic modeling of storage facilities.

Retail gasoline outlet. An operating gasoline or diesel fueling facility whose primary function is the resale of fuels. The term applies to facilities that create five thousand (5,000) or more square feet of impervious surfaces, or generate an average daily traffic count of one hundred (100) vehicles per one thousand (1,000) square feet of land area.

Retention basin. A type of storage practice, that has no positive outlet, used to retain storm water run-off for an indefinite amount of time. Runoff from this type of basin is removed only by infiltration through a porous bottom or by evaporation.

Retention. The storage of stormwater to prevent it from leaving the development site. May be temporary or permanent.

Retention Facility. A facility designed to completely retain a specified amount of stormwater runoff without release except by means of evaporation, infiltration or pumping. The volumes are often referred to in units of acre-feet.

Return Period - The average interval of time within which a given rainfall event will be equaled or exceeded once. A flood having a return period of 100 years has a one percent probability of being equaled or exceeded in any one year.

Revetment. Facing of stone or other material, either permanent or temporary, placed along the edge of a stream to stabilize the bank and protect it from the erosive action of the stream.

Revetment Riprap. Material graded such that: (1) no individual piece weighs more than 120 lbs. and (2) 90-100% will pass through a 12-inch sieve, 20-60% through a 6-inch sieve, and not more than 10% through a 12-inch sieve.

Right-of-Way for a County Drain. The statutory right of way as defined by Indiana Code for a regulated drain.

Riparian habitat. A land area adjacent to a waterbody that supports animal and plant life associated with that waterbody.

Riparian zone. Of, on, or pertaining to the banks of a stream, river, or pond.

Riprap. Broken rock, cobble, or boulders placed on earth surfaces, such as the face of a dam or the bank of a stream, for protection against the action of water (waves).

River Restoration. Restoring the channel of a stream or ditch to its perceived original, non-obstructed capacity by means of clearing & snagging, obstruction removal, and inexpensive streambank protection measures. The term "restoration", as noted, does <u>not</u> necessarily imply restoration or improvement of water quality or habitat within the channel or its adjacent area.

Riverine. Relating to, formed by, or resembling a stream (including creeks and rivers).

Runoff Coefficient - A decimal fraction relating the amount of rain which appears as runoff and reaches the storm drain system to the total amount of rain falling. A coefficient of 0.5 implies that 50 percent of the rain falling on a given surface appears as storm water runoff.

Runoff. That portion of precipitation that flows from a drainage area on the land surface, in open channels, or in stormwater conveyance systems.

Sand. (1) Soil particles between 0.05 and 2.0 mm in diameter. (2) A soil textural class inclusive of all soils that are at least 70% sand and 15% or less clay.

Sanitary Backup. The condition where a sanitary sewer reaches capacity and surcharges into the lowest area.

Scour. The clearing and digging action of flowing water.

Sediment. Solid material (both mineral and organic) that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface.

Sediment Forebay. See "Forebay".

Sedimentation. The process that deposits soils, debris and other unconsolidated materials either on the ground surfaces or in bodies of water or watercourses.

Seepage. The passage of water or other fluid through a porous medium, such as the passage of water through an earth embankment or masonry wall.

Sensitive Water. A water body in need of priority protection or remediation base on its:

providing habitat for threatened or endangered species,

usage as a public water supply intake,

relevant community value,

usage for full body contact recreation,

exceptional use classification as found in 327 IAC 2-1-11(b), outstanding state resource water classification as found in 327 IAC 2-1-2(3) and 327 IAC 2-1.5-19(b).

Settling Basin. An enlargement in the channel of a stream to permit the settling of debris carried in suspension.

Silt Fence. A fence constructed of wood or steel supports and either natural (e.g. burlap) or synthetic fabric stretched across area of non-concentrated flow during site development to trap and retain on-site sediment due to rainfall runoff.

Silt. (1) Soil fraction consisting of particles between 0.002 and 0.05 mm in diameter. (2) A soil textural class indicating more than 80% silt.

Siphon - A closed conduit or portion of which lies above the hydraulic grade line, resulting in a pressure less than atmospheric and requiring a vacuum within the conduit to start flow. A siphon utilizes atmospheric pressure to effect or increase the flow of water through a conduit. An inverted siphon is used to carry storm water flow under an obstruction such as a sanitary sewer.

Site. The entire area included in the legal description of the land on which land disturbing activity is to be performed.

Slope. Degree of deviation of a surface from the horizontal, measured as a numerical ratio or percent. Expressed as a ratio, the first number is commonly the horizontal distance (run) and the second is the vertical distance (rise)--e.g., 2:1. However, the preferred method for designation of slopes is to clearly identify the horizontal (H) and vertical (V) components (length (L) and Width (W) components for horizontal angles). Also note that according to international standards (Metric), the slopes are presented as the vertical or width component shown on the numerator--e.g., 1V:2H. Slope expressions in the Resolution follow the common presentation of slopes--e.g., 2:1 with the metric presentation shown in parenthesis--e.g., (1V:2H). Slopes can also be expressed in "percents". Slopes given in percents are always expressed as (100*V/H) --e.g., a 2:1 (1V:2H) slope is a 50% slope.

Soil and Water Conservation District. A public organization created under state law as a special-purpose district to develop and carry out a program of soil, water, and related resource conservation, use, and development within its boundaries. A subdivision of state government with a local governing body, established under IC 14-32.

Soil. The unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants.

Solid Waste. Any garbage, refuse, debris, or other discarded material.

Special Flood Hazard Area. An area that is inundated during the 100-Year flood.

Spill. The unexpected, unintended, abnormal, or unapproved dumping, leakage, drainage, seepage, discharge, or other loss of petroleum, hazardous substances, extremely hazardous substances, or objectionable substances. The term does not include releases to impervious surfaces when the substance does not migrate off the surface or penetrate the surface and enter the soil.

Spillway - A waterway in or about a hydraulic structure, for the escape of excess water.

Standard Project Flood. A term used by the U.S. Army Corps of Engineers to designate a flood that may be expected from the most severe combination of meteorological and hydrological conditions that are considered reasonable characteristics of the geographical area in which the drainage basin is located, excluding extremely rare combinations. The peak flow for a standard project flood is generally 40 – 60 percent of the probable maximum flood for the same location.

Stilling Basin - A basin used to slow water down or dissipate its energy.

Storage practices. Any structural BMP intended to store or detain stormwater and slowly release it to receiving waters or drainage systems. The term includes detention and retention basins.

Storm drain signing. Any marking procedure that identifies a storm sewer inlet as draining directly to a receiving waterbody so as to avoid dumping pollutants. The procedures can include painted or cast messages and adhesive decals.

Storm Duration. The length of time that water may be stored in any stormwater control facility, computed from the time water first begins to be stored.

Storm Event. An estimate of the expected amount of precipitation within a given period of time. For example, a 10-yr. frequency, 24-hr. duration storm event is a storm that has a 10% probability of occurring in any one year. Precipitation is measured over a 24-hr. period.

Storm Frequency. The time interval between major storms of predetermined intensity and volumes of runoff (e.g. a 5-yr., 10-yr., or 20-yr. storm).

Storm Sewer. A closed conduit for conveying collected storm water, while excluding sewage and industrial wastes. Also called a storm drain.

Stormwater. Water resulting from rain, melting or melted snow, hail, or sleet.

Stormwater Drainage System - All means, natural or man-made, used for conducting storm water to, through or from a drainage area to any of the following: conduits and appurtenant features, canals, channels, ditches, storage facilities, swales, streams, culverts, streets and pumping stations.

Stormwater Facility. All ditches, channels, conduits, levees, ponds, natural and manmade impoundments, wetlands, tiles, swales, sewers and other natural or artificial means of draining surface and subsurface water from land.

Stormwater Pollution Prevention Plan. A plan developed to minimize the impact of storm water pollutants resulting from construction activities.

Stormwater Quality Management Plan. A comprehensive written document that addresses stormwater runoff quality.

Stormwater Quality Measure. A practice, or a combination of practices, to control or minimize pollutants associated with storm water runoff.

Stormwater runoff. The water derived from rains falling within a tributary basin, flowing over the surface of the ground or collected in channels or conduits.

Stream. See Intermittent stream, Perennial stream, Receiving stream.

Streambanks. The usual boundaries (not the flood boundaries) of a stream channel. Right and left banks are named facing downstream.

Stream Gaging. The quantitative determination of streamflow using gauges, current meters, weirs, or other measuring instruments at selected locations (see Gaging Station).

Stream Length. The length of a stream or ditch, expressed in miles, from the confluence of the stream or ditch with the receiving stream to the upstream extremity of the stream or ditch, as indicated by the solid or dashed, blue or purple line depicting the stream or ditch on the most current edition of the seven and one-half (72) minute topographic quadrangle map published by the United States Geological Survey, measured along the meanders of the stream or ditch as depicted on the map.

Strip development. A multi-lot project where building lots front on an existing road.

Structure. Refers to a structure that is principally above ground and is enclosed by walls and a roof. The term includes but is not limited to, a gas or liquid storage tank, a manufactured home or a prefabricated building, and recreational vehicles to be installed on a site for more than 180 days.

Structural Engineer. A person licensed under the laws of the State of Indiana to engage in the designing or supervising of construction, enlargement or alteration of structures or any part thereof.

Structural Floodplain Management Measures. Those physical or engineering measures employed to modify the way floods behave, (e.g., dams, dikes, levees, channel enlargements and diversions).

Subarea/Subbasin. Portion of a watershed divided into homogenous drainage units which can be modeled for purposes of determining runoff rates. The subareas/subbasins have distinct boundaries, as defined by the topography of the area.

Subdivision. Any land that is divided or proposed to be divided into lots, whether contiguous or subject to zoning requirements, for the purpose of sale or lease as part of a larger common plan of development or sale.

Subdivision, Minor. The subdivision of a parent parcel into any combination of not more than three (3) contiguous or non-contiguous new residential, commercial, or industrial building sites. The parcel shall front upon an existing street which is an improved right-of-way maintained by the County or other governmental entity and not involve any new street.

Subsoil. The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below which roots do not normally grow.

Subsurface Drain. A pervious backfield trench, usually containing stone and perforated pipe, for intercepting groundwater or seepage.

Subwatershed. A watershed subdivision of unspecified size that forms a convenient natural unit. See also Subarea.

Sump Failure. A failure of the sump pump that results in inundation of crawl space or basement.

Sump Pump. A pump that discharges seepage from foundation footing drains.

Surcharge. Backup of water in a sanitary or storm sewer system in excess of the design capacity of the system.

Surface Runoff. Precipitation that flows onto the surfaces of roofs, streets, the ground, etc., and is not absorbed or retained by that surface but collects and runs off.

Suspended Solids. Solids either floating or suspended in water.

Swale. An elongated depression in the land surface that is at least seasonally wet, is usually heavily vegetated, and is normally without flowing water. Swales conduct stormwater into primary drainage channels and may provide some groundwater recharge.

Tailwater. The water surface elevation at the downstream side of a hydraulic structure (i.e. culvert, bridge, weir, dam, etc.).

Temporary Stabilization. The covering of soil to ensure its resistance to erosion, sliding, or other movement. The term includes vegetative cover, anchored mulch, or other non-erosive material applied at a uniform density of seventy percent (70%) across the disturbed area.

Thalweg. The deepest point (or centerline) of a channel.

Tile Drain. Pipe made of perforated plastic, burned clay, concrete, or similar material, laid to a designed grade and depth, to collect and carry excess water from the soil.

Tile Drainage. Land drainage by means of a series of tile lines laid at a specified depth, grade, and spacing.

Time of Concentration (tc). The travel time of a particle of water from the most hydraulically remote point in the contributing area to the point under study. This can be considered the sum of an overland flow time and times of travel in street gutters, storm sewers, drainage channels, and all other drainage ways.

Topographic Map. Graphical portrayal of the topographic features of a land area, showing both the horizontal distances between the features and their elevations above a given datum.

Topography. The representation of a portion of the earth's surface showing natural and man-made features of a give locality such as rivers, streams, ditches, lakes, roads, buildings and most importantly, variations in ground elevations for the terrain of the area.

Topsoil. (1) The dark-colored surface layer, or a horizon, of a soil; when present it ranges in depth from a fraction of an inch to 2-3 ft. (2) Equivalent to the plow layer of cultivated soils. (3) Commonly used to refer to the surface layer(s), enriched in organic matter and having textural and structural characteristics favorable for plant growth.

Total Maximum Daily Load. Method used to establish allowable loadings for specified pollutants in a surface water resource to meet established water quality standards.

Toxicity. The characteristic of being poisonous or harmful to plant or animal life. The relative degree or severity of this characteristic.

TP-40 Rainfall. Design storm rainfall depth data for various durations published by the National Weather Service in their Technical Paper 40 dated 1961.

Trained individual. An individual who is trained and experienced in the principles of storm water quality, including erosion and sediment control as may be demonstrated by state registration, professional certification (such as CESSWI and/or CPESC certification), or other documented and applicable experience or coursework as deemed sufficient by the City that enable the individual to make judgments regarding storm water control or treatment and monitoring.

Transition Section. Reaches of the stream of floodway where water flows from a narrow cross-section to a wide cross-section or vice-versa.

Tributary. Based on the size of the contributing drainage area, a smaller watercourse which flows into a larger watercourse.

Turbidity. (1) Cloudiness of a liquid, caused by suspended solids. (2) A measure of the suspended solids in a liquid.

Underdrain. A small diameter perforated pipe that allows the bottom of a detention basin, channel or swale to drain.

Unified Soil Classification System. A system of classifying soils that is based on their identification according to particle size, gradation, plasticity index, and liquid limit.

Uniform Flow. A state of steady flow when the mean velocity and cross-sectional area remain constant in all sections of a reach.

Unit Hydrograph. The hydrograph that results from one inch of precipitation excess generated uniformly over the watershed at a uniform rate during a specified period of time.

Urban Drain. A drain defined as “Urban Drain” in Indiana Drainage Code.

Urbanization The development, change or improvement of any parcel of land consisting of one or more lots for residential, commercial, industrial, institutional, recreational or public utility purposes.

Vegetated swale. A type of vegetative practice used to filter stormwater runoff via a vegetated, shallow-channel conveyance.

Vegetative practices. Any nonstructural or structural BMP that, with optimal design and good soil conditions, utilizes various forms of vegetation to enhance pollutant removal, maintain and improve natural site hydrology, promote healthier habitats, and increase aesthetic appeal. Examples include grass swales, filter strips, buffer strips, constructed wetlands, and rain gardens.

Vegetative Stabilization. Protection of erodible or sediment producing areas with: permanent seeding (producing long-term vegetative cover), short-term seeding (producing temporary vegetative cover), or sodding (producing areas covered with a turf of perennial sod-forming grass).

Water Course. Any river, stream, creek, brook, branch, natural or man-made drainage way in or into which stormwater runoff or floodwaters flow either regularly or intermittently.

Water Quality. A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water Resources. The supply of groundwater and surface water in a given area.

Water Table. (1) The free surface of the groundwater. (2) That surface subject to atmospheric pressure under the ground, generally rising and failing with the season or from other conditions such as water withdrawal.

Waterbody. Any accumulation of water, surface, or underground, natural or artificial.

Watercourse. Any river, stream, creek, brook, branch, natural or man-made drainageway in or into which stormwater runoff or floodwaters flow either continuously or intermittently.

Watershed Area. All land and water within the confines of a drainage divide. See also Watershed.

Watershed. The region drained by or contributing water to a specific point that could be along a stream, lake or other stormwater facilities. Watersheds are often broken down into subareas for the purpose of hydrologic modeling.

Waterway. A naturally existing or manmade open conduit or channel utilized for the conveyance of water.

Weir. A channel-spanning structure for measuring or regulating the flow of water.

Wellhead protection area. Has the meaning set forth in 327 IAC 8-4.1-1(27).

Wet-Bottom Detention Basin (Retention Basin) - A basin designed to retain a permanent pool of water after having provided its planned detention of runoff during a storm event.

Wetlands. Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

APPENDIX B

Applications, Forms and Miscellaneous Sheets required to Comply with the City of Fishers Stormwater Management Resolution

B1 – Conceptual Drainage Plan Review Forms
Conceptual Drainage Plan Review Requirements

B2 – Stormwater Plan Review Forms
Drainage and Water Quality Plan Review Requirements
Notice of Intent – State Form #47487

B3 – Construction Inspection/Completion Forms
Construction Site Inspection and Maintenance Log
Certification of Completion & Compliance
Notice of Termination – State Form #51514
Notice of Termination Inspection

B4 – Individual Residential Lot Permit Forms
Instructions for Residential Plot Plan Permit Request
Residential Lot Plot Plan Permit Request Application
Individual Lot Typical Erosion & Sediment Control Plan and Certification

B1 – Conceptual Drainage Plan Review Forms

Conceptual Drainage Plan Review Requirements

City of Fishers **Conceptual Drainage Plan Review Requirements**		
Project Name:		
General Location:		
File Number:		Date Completed:

1. Application Fee

	Check Attached.

2. Letter of Intent

	Letter of Intent for obtaining any needed consents, off-site easements, or right-of-way.

3. Project Narrative and Supporting Documents

		Description of the nature and purpose of the project.
		General description of the existing and proposed drainage systems in narrative form.
		General description of regulated drains, farm drains, inlets and outfalls in narrative form, if any of record.
		General description of all existing storm, sanitary, combined sewer, and septic tank systems and outfalls in narrative form.
		Vicinity map depicting the project site location in relation to recognizable local landmarks, towns, and major roads, such as a USGS topographic quadrangle map or county or municipal road map.
		A map showing the location, name, and normal water level of all wetlands, lakes, ponds, and water courses on or adjacent to the project site.
		A map showing one hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.
		A map showing watershed boundaries with USGS contours or best information possible.
		A map showing existing watercourse or regulated drains.

4. Conceptual Plans

	Two (2) complete sets of conceptual plans showing general project layout, including existing and proposed drainage systems and proposed outlets (plan sheets must be larger than 11” by 17”, but not to exceed 24” by 36”).

B2 – Stormwater Plan Review Forms

Drainage and Water Quality Plan Review Requirements
Notice of Intent – State Form #47487

City of Fishers
Drainage and Water Quality Plan Review Requirements

Project Name:	
General Location:	
File Number:	Date Completed:

1. Application Fee

	Applicant will be notified of the application fees after assessment of the plan submittal.

2. Notice of Intent

	Completed Draft Notice of Intent (Final NOI submitted after SWPPP approval)-- State Form #47487

3. Construction Plans

	Title sheet which includes location map, vicinity map, operating authority, design company name, developer name, and index of plan sheets.	
	A copy of a legal boundary survey for the site, performed in accordance with Rule 12 of Title 865 of the Indiana Administrative Code or any applicable and subsequently adopted rule or regulation for the subdivision limits, including all drainage easements and wetlands.	
	A reduced plat or project site map showing the parcel identification numbers, the lot numbers, lot boundaries, easements, and road layout and names. The reduced map must be legible and submitted on a sheet or sheets no larger than eleven (11) inches by seventeen (17) inches for all phases or sections of the project site.	
	An existing project site layout that must include the following information:	
		A topographic map of the land to be developed and such adjoining land whose topography may affect the layout or drainage of the development. The contour intervals shall be one (1) foot when slopes are less than or equal to two percent (<2%) and shall be two (2) feet when slopes exceed two percent (>2%). All elevations shall be given in either National Geodetic Vertical Datum of 1929 (NGVD) or North American Vertical Datum of 1988 (NAVD). The horizontal datum of topographic map shall be based on Indiana State Plane Coordinates, NAD83. The map will contain a notation indicating these datum information. a] If the project site is less than or equal to two (2) acres in total land area, the topographic map shall include all topography of land surrounding the site to a distance of at least one hundred (100) feet. b] If the project site is greater than two (2) acres in total land area, the topographic map shall include all topography of land surrounding the site to a distance of at least two hundred (200) feet.
		Location, name, and normal water level of all wetlands, lakes, ponds, and water courses on or adjacent to the project site.
		Location of all existing structures on the project site.
		One hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.
		Identification and delineation of vegetative cover such as grass, weeds, brush, and trees on the project site.
		Location of storm, sanitary, combined sewer, and septic tank systems and outfalls.
		Land use of all adjacent properties.
		Identification and delineation of sensitive areas.
		The location of regulated drains, farm drains, inlets and outfalls, if any of record.
		Location of all existing cornerstones within the proposed development and a plan to protect and preserve them.
	A grading and drainage plan, including the following information:	

		All information from the existing site layout items listed above
		Location of all proposed site improvements, including roads, utilities, lot delineation and identification, proposed structures, and common areas.
		One hundred (100) year floodplains, floodway fringes, and floodways. Please note if none exists.
		Delineation of all proposed land disturbing activities, including off-site activities that will provide services to the project site.
		Information regarding any off-site borrow, stockpile, or disposal areas that are associated with a project site, and under the control of the project site owner.
		Existing and proposed topographic information at a contour interval appropriate to indicate drainage patterns.
		Location, size, and dimensions of all existing streams to be maintained, and new drainage systems such as culverts, bridges, storm sewers, conveyance channels, and 100-year overflow paths/ponding areas shown as hatched areas, along with the associated easements.
		Pipes and associated structures data, including sizes, lengths, and material
		Location, size, and dimensions of features such as permanent retention or detention facilities, including existing or manmade wetlands, used for the purpose of stormwater management. Include existing retention or detention facilities that will be maintained, enlarged, or otherwise altered and new ponds or basins to be built.
		Emergency flood routing path(s) and their invert elevations from detention facilities to the receiving system
		One or more typical cross sections of all existing and proposed channels or other open drainage facilities carried to a point above the 100-year high water and showing the elevation of the existing land and the proposed changes, together with the high water elevations expected from the 100 year storm under the controlled conditions called for by the Resolution, and the relationship of structures, streets, and other facilities
		A drainage summary, which summarizes the basic conditions of the drainage design, including site acreage, off-site/upstream acreage, allowable release rates, post-developed 10-year, and 100-year flows leaving the site, volume of detention required, volume of detention provided, and any release rate restrictions
		Arrows designating the direction of stormwater runoff
		Spot elevations appropriate to define elevations
	Utility plan sheet(s) showing the location of all existing and proposed utility lines for the project, including all available information related to the utilities, such as pipe size and material, and invert elevations	
	Storm sewer plan/profile sheet(s) at a scale of 5 vertical and 50 horizontal showing the elevation, size, length, location of al proposed storm sewers. Existing and proposed ground grades, storm sewer structures elevations, and utility crossings also must be included. The actual correct datum (not an assumed one) must be used for the profile sheets and all pipe inverts, top of casting elevations, casting types, structure numbers, and pipe slopes clearly labeled.	
	A 24-inch by 36-inch plat on the same sheet size used for recording, including the following information:	
		Legal description.
		Cross reference to Rule 12.
		Regulated drain statement and table.
	Proposed subdivision landscape plans	
	A copy of the subdivision covenants	
	Any other information required by the Directors of Engineering or Public Works in order to thoroughly evaluate the submitted material.	
4. Stormwater Drainage Technical Report		
	A summary report, including the following information:	
		Description of the nature and purpose of the project.
		The significant drainage problems associated with the project.
		The analysis procedure used to evaluate these problems and to propose solutions.

		Any assumptions or special conditions associated with the use of these procedures, especially the hydrologic or hydraulic methods.
		The proposed design of the drainage control system.
		The results of the analysis of the proposed drainage control system showing that it does solve the project's drainage problems and that it meets the requirements of the ordinance and these standards. This must include a table summarizing, for each eventual site outlet, the pre-developed acreage tributary to each eventual site outlet, the unit discharge allowable release rate used, the resulting allowable release rate in cfs for the post-developed 10-year and 100-year events, pre-developed 2-year flow rates in cfs as well as pre- and post-developed flow rates for 10- and 100-year events. The worksheet provided in the City of Fishers Stormwater Technical Standards Manual as Table 6-1 should be filled and submitted as part of the report. Any hydrologic or hydraulic calculations or modeling results must be adequately cited and described in the summary description. If hydrologic or hydraulic models are used, the input and output files for all necessary runs must be included in the appendices. A map showing any drainage area subdivisions used in the analysis must accompany the report.
		Soil properties, characteristics, limitations, and hazards associated with the project site and the measures that will be integrated into the project to overcome or minimize adverse soil conditions.
		A narrative and photographic record of the condition of the downstream receiving system
		Identification of any other state or federal water quality permits that are required for construction activities associated with the owner's project site.
		Proof of Errors and Omissions Insurance for the registered professional engineer or licensed surveyor showing a minimum amount of $1,000,000 in coverage.
	A Hydrologic/Hydraulic Analysis, consistent with the methodologies and calculation included in the [technical standards], and including the following information:	
		A hydraulic report detailing existing and proposed drainage patterns on the subject site. The report should include a description of present land use and proposed land use. Any off-site drainage entering the site should be addressed as well. This report should be comprehensive and detail all of the steps the engineer took during the design process.
		All hydrologic and hydraulic computations must be included in the submittal. These calculations must include, but are not limited to: runoff curve numbers and runoff coefficients, runoff calculations, stage-discharge relationships, times-of-concentration and storage volumes.
		Copies of all computer runs. These computer runs must include both the input and the outputs. Electronic copies of the computer runs with input files will expedite the review process and is required to be submitted.
		A set of exhibits must be included showing the drainage sub-areas and a schematic detailing of how the computer models were set up.
		A conclusion which summarizes the hydraulic design and details how this design satisfies the Resolution.

5. Stormwater Pollution Prevention Plan for Construction Sites

	Location, dimensions, detailed specifications, and construction details of all temporary and permanent stormwater quality measures.
	Soil map of the predominant soil types, as determined by the United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS) Soil Survey, or as determined by a soil scientist. Hydrologic classification for soils should be shown when hydrologic methods requiring soils information are used. A soil legend must be included with the soil map.
	14-Digit Watershed Hydrologic Unit Code.
	An estimate of the peak discharge, based on the ten (10) year storm event, of the project site for post-construction conditions.
	Locations where stormwater may be directly discharged into groundwater, such as abandoned wells or sinkholes. Please note if none exists.
	Locations of specific points where stormwater discharge will leave the project site.

	Name of all receiving waters. If the discharge is to a separate municipal storm sewer, identify the name of the municipal operator and the ultimate receiving water.	
	Temporary stabilization plans and sequence of implementation.	
	Permanent stabilization plans and sequence of implementation.	
	Temporary and permanent stabilization plans shall include the following:	
		Specifications and application rates for soil amendments and seed mixtures.
		The type and application rate for anchored mulch.
	General construction sequence of how the project site will be built, including phases of construction.	
	Construction sequence describing the relationship between implementation of stormwater quality measures and stages of construction activities.	
	Location of all soil stockpiles and borrow areas.	
	A typical erosion and sediment control plan for individual lot development.	
	Self-monitoring program including plan and procedures.	
	A description of potential pollutant sources associated with the construction activities, which may reasonably be expected to add a significant amount of pollutants to stormwater discharges.	
	Material handling and storage associated with construction activity shall meet the spill prevention and spill response requirements in 327 IAC 2-6.1.	
	Name, address, telephone number, and list of qualifications of the trained individual in charge of the mandatory stormwater pollution prevention self-monitoring program for the project site.	
6. Post-Construction Storm Water Pollution Prevention Plan		
	A description of potential pollutant sources from the proposed land use, which may reasonably be expected to add a significant amount of pollutants to stormwater discharges.	
	Location, dimensions, detailed specifications, and construction details of all post-construction stormwater quality measures.	
	A description of measures that will be installed to control pollutants in stormwater discharges that will occur after construction activities have been completed. Such practices include infiltration of run-off, flow reduction by use of open vegetated swales and natural depressions, buffer strip and riparian zone preservation, filter strip creation, minimization of land disturbance and surface imperviousness, maximization of open space, and stormwater retention and detention ponds.	
	A sequence describing when each post-construction stormwater quality measure will be installed.	
	Stormwater quality measures that will remove or minimize pollutants from stormwater run-off.	
	Stormwater quality measures that will be implemented to prevent or minimize adverse impacts to stream and riparian habitat.	
	An operation and maintenance manual for all post-construction stormwater quality measures to facilitate their proper long term function. This operation and maintenance manual shall be made available to future parties who will assume responsibility for the operation and maintenance of the post-construction stormwater quality measures. The manual shall also be recorded at the Hamilton County Recorder's Office and associated with the property deed. Prior to issuance of the Notice of Intent for the development, a copy of a signed document by both the developer and the new owner (i.e. HOA) shall also be recorded that indicates that the BMP responsibilities have been appropriately transferred to the new party. The manual shall include the following:	
		Contact information for the BMP owner (i.e. name, address, business phone number, cell phone number, pager number, e-mail address, etc.).
		A statement that the BMP owner is responsible for all costs associated with maintaining the BMP. A signed owner acknowledgement form indicating the owner is aware of the location of the BMP and the said maintenance and inspection responsibilities associated with it.
		A right-of-entry statement allowing City personnel to inspect and maintain the BMP.
		Specific actions to be taken regarding routine maintenance, remedial maintenance of structural components, and sediment removal. Sediment removal procedures should be explained in both narrative and graphical forms. A tabular schedule should be provided listing all maintenance activities and dates for performing these required maintenance activities.
		Site drawings showing the location of the BMP and access easement, cross sections of BMP features (i.e. pond, forebay(s), structural components, etc.), and the point of discharge for

		stormwater treated by the BMP. These drawings need to be submitted both in hard copy and in digital format acceptable to the City of Fishers.

RULE 5 - NOTICE OF INTENT (NOI)
State Form 47487 (R6 / 2-15)
Indiana Department of Environmental Management
Office of Water Quality
Approved by State Board of Accounts, 2005

Type of Submittal *(Check Appropriate Box):* ☐ Initial ☐ Amendment ☐ Renewal
Permit Number: *(Note: The initial submittal does not require a permit number; the Department will assign a number. A permit number is required when filing an amendment, applying for renewal, or correspondence related to this permit).*

Note: Submission of this Notice of Intent letter constitutes notice that the project site owner is applying for coverage under the National Pollutant Discharge Elimination System (NPDES) General Permit Rule for Storm Water Discharges Associated with Construction Activity. Permitted project site owners are required to comply with all terms and conditions of the General Permit Rule 327 IAC 15-5 (Rule 5).

NAME AND LOCATION OF PROJECT

Name of Project:	County:
Brief Description of Project Location:	
Project Location: *Describe location in Latitude and Longitude (Degrees, Minutes, and Seconds or Decimal representation) and by legal description (Section, Township, and Range, Civil Township)*	
Latitude:	Longitude:

Quarter: Section: Township: Range: Civil Township:

Does ☐ all or ☐ part of this project lie within the jurisdictional boundaries of a Municipal Separate Storm Sewer System (MS4) as defined in 327 IAC 15-13?
☐ Yes ☐ No If yes, name the MS4(s):

SITE OWNER OF PROJECT AND CONTACT INFORMATION OF PROJECT

Name of Company *(If Applicable)*:			
Name of Project Site Owner: *(An Individual)*			Title/Position:
Address:			
City:		State:	ZIP Code:
Phone:	FAX:	E-Mail Address: *(If Available)*	

Ownership Status *(check one)*:
Governmental Agency: ☐ Federal ☐ State ☐ Local Non-Governmental: ☐ Public ☐ Private ☐ Other: *(Explain)*

Contact Person:		Name of Company: *(If Applicable)*	
Affiliation to Project Site Owner:			
Address: *(if different from above)*			
City:		State:	ZIP Code:
Phone:	FAX:	E-Mail Address: *(If Available)*	

PROJECT INFORMATION

Project Description:
☐ Residential-Single Family ☐ Residential-Multi-Family ☐ Commercial ☐ Industrial ☐ Other: *(Explain)*

Name of Receiving Water:

(Note: If applicable, name of municipal operator of storm sewer and the ultimate receiving water. If a retention pond is present on the property, the name of the nearest possible receiving water receiving discharge must be provided).

Project Acreage
Total Acreage: Proposed Land Disturbance: *(in acres)*
Total Impervious Surface Area: *(in square feet, estimated for completed project)*

Project Duration
Estimated Start Date: Estimated End Date for all Land Disturbing Activity:

(Continued on Reverse Side)

CONSTRUCTION PLAN CERTIFICATION

By signing this Notice of Intent letter, I certify the following:

A. The storm water quality measures included in the Construction Plan comply with the requirements of 327 IAC 15-5-6.5, 327 IAC 15-5-7, and 327 IAC 15-5-7.5;
B. the storm water pollution prevention plan complies with all applicable federal, state, and local storm water requirements;
C. the measures required under 327 IAC 15-5-7 and 327 IAC 15-5-7.5 will be implemented in accordance with the storm water pollution prevention plan;
D. if the projected land disturbance is One (1) acre or more, the applicable Soil and Water Conservation District or other entity designated by the Department, has been sent a copy of the Construction Plan for review;
E. storm water quality measures beyond those specified in the storm water pollution prevention plan will be implemented during the life of the permit if necessary to comply with 327 IAC 15-5-7; and
F. implementation of storm water quality measures will be inspected by trained individuals.

In addition to this form, I have enclosed the following required information:

☐ Verification by the reviewing agency of acceptance of the Construction Plan.

☐ Proof of publication in a newspaper of general circulation in the affected area that notified the public that a construction activity is to commence, including all required elements contained in 327 IAC 15-5-5 (9). The Proof of Publication **Must** include company name and address, project name, address/location of the project, and the receiving stream to which storm water will be discharged. Following is a sample Proof of Publication:

"XERT Development Inc. (10 Willow Lane, Indianapolis, Indiana 46206) is submitting a Notice of Intent to the Indiana Department of Environmental Management of our intent to comply with the requirements of 327 IAC 15-5 to discharge storm water from construction activities associated with Water Garden Estates located at 24 Washout Lane, Indianapolis, Indiana 46206. Runoff from the project site will discharge to the White River. Questions or comments regarding this project should be directed to Walter Water of XERT Development Inc."

☐ $100 check or money order payable to the Indiana Department of Environmental Management. A permit fee is required for all NOI submittals (initial and renewal). A fee is not required for amendments.

SITE OWNER OF PROJECT RESPONSIBILITY STATEMENT

By signing this Notice of Intent letter, I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information or violating the provisions of 327 IAC 15-5, including the possibility of fine and imprisonment for knowing violations.

Printed Name of Project Owner: ____

Signature of Project Owner: ______________________________ Date *(month, day, year)*: ______________

This Notice of Intent must be signed by an individual meeting the signatory requirements in 327 IAC 15-4-3(g).
All NOI submittals must include an original signature (FAX and photo copies are not acceptable).

Note: Within 48 hours of the initiation of construction activity, the project site owner must notify the appropriate plan review agency and IDEM, Office of Water Quality of the actual project start date if it varies from the date provided above.

Note: A permit issued under 327 IAC 15-5 is granted by the commissioner for a period of five (5) years from the date coverage commences. Once the five (5) year permit term duration is reached, a general permit issued under this rule will be considered expired, and as necessary for construction activity continuation, a new Notice of Intent letter (Renewal) is required to be submitted ninety (90) days prior to the termination of coverage. The submittal must include the NOI Letter, Proof of Publication, Fee, and verification that the plan for the project was approved (original verification of plan approval is acceptable provided the scope of the project has not changed from the original submittal).

Mail this form to: **Indiana Department of Environmental Management**
Storm Water Program, IGCN, Room 1255
100 North Senate Avenue
Indianapolis., IN 46204-2251

327 IAC 15-5-6 (a) also requires a copy of the completed Notice of Intent letter be submitted to the local Soil and Water Conservation District or other entity designated by the Department, where the land disturbing activity is to occur.

Questions regarding the development or implementation of the Construction Plan/Storm Water Pollution Prevention Plan should be directed to the local county Soil and Water Conservation District (SWCD). If you are unable to reach the SWCD or have other questions please direct those inquiries to the IDEM Storm Water Permit Coordinator at 317/233-1864 or 800/451-6027 ext.3-1864.
For information and forms visit http://www.in.gov/idem/4896.htm .

B3 – Construction Inspection/Completion Forms

Construction Site Inspection and Maintenance Log
Certification of Completion & Compliance
Notice of Termination – State Form #51514
Notice of Termination Inspection

Date: ____________________ Project: ____________________ Inspected by: ____________________

Type of Inspection: ☐ Scheduled Weekly - or - ☐ Rain Event *(record rain event amount ______)*

CONSTRUCTION SITE SELF-INSPECTION AND MAINTENANCE LOG

(To be Completed by A "Trained Individual")

I certify under penalty of law that this document was completed to the best of my knowledge and belief on the date listed below per my signature. I am aware that there are significant penalties for submitting false information, including the possibility of loss of TI Certification, fine and imprisonment for knowing violations.

Signature of Trained Individual:	***Date:***

All stormwater pollution prevention BMP's shall be inspected and maintained as needed to ensure continued performance of their intended function during construction and shall continue until the entire site has been stabilized and a Notice of Termination has been issued. An inspection of the project site must be completed by the end of the next business day following each measurable (½ inch or more) storm event. If there are no measurable storm events within a given week, the site should be inspected at least once in that week. Maintenance and repair shall be completed promptly in accordance with the accepted site plans. This log shall be kept as a permanent record and must be made available to the local municipality, in an organized fashion, within forty-eight (48) hours of a request.

ITEM		**YES**	**NO**	**n/a**
Procedural Items				
1.	Is the Rule 5 NOI, contact information, and location of construction plans & SWPPP posted at the entrance?			
Tracking Controls				
2.	Is a construction entrance installed per plan and functioning properly at all approved access points?			
3.	Are construction staging & parking areas restricted to stabilized areas designated on the plans?			
4.	Are public and private streets clean of sediment, debris and mud?			
Materials Management				
5.	Is a designated concrete - mortar - paint washout area properly installed - clearly marked - stable access - being utilized and maintained? Is it located away from swales, inlets, or other stormwater conveyances?			
6.	Are fuel tanks and other hazardous materials safely stored and protected? Are all such materials located on stable surface away from swales, inlets, or other stormwater conveyances?			
7.	Are portable toilets placed behind the curb, anchored, and located away from swales, inlets, or other stormwater conveyances?			
8.	Is spill response equipment on-site and easily accessible?			
9.	Are all chemical storage areas and equipment being properly managed and free of leaks and or spills?			

	Materials Management (cont.)	YES	NO	n/a
10.	Are temporary soil stockpiles in approved areas & properly protected?			
11.	Is solid waste properly contained & a stable access provided to the storage & pickup area?			
	Perimeter Controls			
12.	Has all silt fence been installed properly and being maintained? (entrenched - upright - fabric not torn - terminated to higher ground - properly joined at ends)			
13.	Are other perimeter protections in place and functioning properly? (have capacity - are cleaned out)			
	Flow Controls			
14.	Are practices installed and effective where storm water leaves the site?			
15.	Are all stormwater discharge points (outfalls) adequately stabilized, free of erosion and sediment transport?			
16.	Are check dams, sediment basins & traps installed according to plan and properly maintained?			
17.	Have swales and ditches been stabilized or protected?			
18.	Are diversion swales, berms and/or waterbars installed to plan & protected?			
	Dewatering and Inlet Protection			
19.	Do dewatering operations have a protected intake and outlet and stabilized discharge point?			
20.	Are all dewatering practices functioning properly and discharging clear water? (dewatering bag – wellpoint – skimmer – scour pad)			
21.	Is inlet protection installed properly on all inlets & being maintained? (properly secured – overflow functional – clean)			
	Site Stabilization			
22.	Has temporary stabilization of unworked/dormant ground been implemented? (15 day rule)			
23.	Is permanent stabilization implemented as final grading is completed?			
24.	Are permanent flow channels, swales, pond banks, and slopes greater than 3:1 erosion free and have seed and erosion blanket installed upon completion per plan?			
25.	Are dust control measures being implemented as needed?			
	Post-Construction BMP / Water Quality unit, device or feature			
26.	Is the Post-Construction water quality device or feature adequately protected from construction phase contamination?			

If you answered "no" to any of the above questions, utilize the attached Corrective Action Log to describe appropriate corrective action(s) which must be taken to remedy the problem and log when the corrective action(s) are completed.

	Overall Site Evaluation			
27.	Has sediment left the site? *(If YES, ensure that the appropriate section above is properly marked and Corrective Actions are identified and completed).*			

Date: ______________________________ Project: ______________________________ Inspected by: ______________________________

Type of Inspection: ☐ Scheduled Weekly - or - ☐ Rain Event *(record rain event amount ______)*

Corrective Action Log

Item # from pgs 1-2	Location	Correction Needed	Date Completed	Initials	Notes

Utilize additional pages as needed.

Certification of Completion & Compliance

CERTIFICATE OF COMPLETION & COMPLIANCE

Address of premises on which land alteration was accomplished:_________________________________
____
____

Inspection Date(s):________________________ Permit Number:______________________________

Relative to plans prepared by:_______________________ on________________________________
(date)

I hereby certify that:

1. I am familiar with drainage requirements applicable to such land alteration (as set forth in the Stormwater Management Resolution of City of Fishers); and

2. I (or a person under my direct supervision) have personally inspected the completed work and examined the drainage permit and its conditions, as-built plans, and final drainage calculations consistent with as-built conditions performed pursuant to the above referenced drainage permit; and

3. To the best of my knowledge, information, and belief, such land alteration has been performed and completed in conformity with all such drainage requirements, except ______________
____
____

Signature: ___________________________ Date: _________________________

Typed or Printed Name: ___________________________ Phone: (___)____________________

(SEAL)

Business Address: _____________________________
____
____
____

SURVEYOR ENGINEER
(circle one)

Indiana Registration No.______________________

RULE 5 – NOTICE OF TERMINATION

State Form 51514 (R3 / 11-15)
INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEME
OFFICE OF WATER QUALITY

Mail this form to:
IDEM, OWQ
Storm Water Program
100 North Senate Avenue
Room 1255
Indianapolis, IN 46204-2251

For questions regarding the requirements for project termination or completion of this form, contact:

Storm Water Permits Coordinator
100 North Senate Avenue
Room 1255

Telephone: (317) 233-1864 or
(800) 451-6027(*within Indiana*), ext. 31864
Web Access: http://www.IN.gov/idem/stormwater/2377.htm

Note: Submission of this Notice of Termination letter is a certification by the project site owner that the project meets the terms and conditions of the General Permit Rule 327 IAC 15-5 (Rule 5, Storm Water Discharges Associated with Construction Activity) for termination of permit coverage under the National Pollutant Discharge Elimination System (NPDES).

PROJECT NAME AND LOCATION

Permit number
(Note: Permit numbers were assigned to projects beginning in November of 2003. Therefore, a permit number is only applicable for those projects that began or were renewed on or after November of 2003).

Project name *(Note: Provide the project name as it appears on the active "Notice of Intent")*		**County**
Company name		
Project site owner's name (*an individual*)		
Address (*number and street)*		
City	**State**	**ZIP code**
Telephone / **FAX**	**E-mail address** *(if available*)	

THIS "NOTICE OF TERMINATION" IS BEING SUBMITTED FOR THE FOLLOWING

To be eligible for termination, specific criteria must be met. There are three options for which a project may be considered for termination. These options include:

- Option # 1 Certification for change of ownership;
- Option # 2 Certification for termination of construction activities *(327 IAC 15-5-8)*; and,
- Option # 3 Notice of termination to obtain early release from compliance with 327 IAC 15-5 (327 IAC 15-5-8).

Select one of the three options that apply to "Permit Termination" by checking the appropriate box, complete all information associated with that option, include required attachments (where applicable), and complete the "Project Site Owner Responsibility Statement" on page 2 of this form.

☐ **Option # 1 Certification for change of ownership**

This option does not apply to the sale of individual lots within the permitted acreage; only the sale of the entire project site as originally permitted. The agency may accept termination for entire sections or phases of a project that are sold. To determine if a project is eligible, please contact the IDEM Storm Water Permits Coordinator.

By signing this "Notice of Termination," I certify the following:

A. **The project was sold**; I am no longer the project site owner as was designated in my "Notice of Intent". The new owner of the project site is:

Company name (*If applicable*)

Project site owner's name (*An individual*)

Address (*number and street)*

City **State** **ZIP code**

Telephone number **FAX** **E-mail Address** (*If available*)

B. I have notified the new project site owner of his/her responsibilities to comply with 327 IAC 15-5 and the requirements associated with the rule including filing a new "Notice of Intent."

☐ **Option # 2 Certification for termination of construction activities**

By signing this "Notice of Termination," I certify the following:

G. All land disturbing activities, including construction on all building lots, have been completed and the entire site has been stabilized;
H. All temporary erosion and sediment control measures have been removed; and
I. No future land disturbing activities will occur at the project site.

(Continued on reverse side)

☐ **Option # 3 "Notice of Termination" to obtain early release from compliance with 327 IAC 15-5**

By signing this "Notice of Termination," I certify the following:

A. The remaining, undeveloped acreage does not exceed five (5) acres, with contiguous areas not to exceed one (1) acre.
B. A map of the project site, clearly identifying all remaining undeveloped lots, is attached to this letter. The map must be accompanied by a list of names and addresses of individual lot owners or individual lot operators of all undeveloped lots.
C. All public and common improvements, including infrastructure, have been completed and permanently stabilized and have been transferred to the appropriate local entity.
D. The remaining acreage does not pose a significant threat to the integrity of the infrastructure, adjacent properties, or water quality.
E. All permanent storm water quality measures have been implemented and are operational.

Upon written notification to the department the project site owner certifies that he/she will:

A. Notify all current individual lot owners and all subsequent lot owners of the remaining undeveloped acreage and acreage with construction activity that they are responsible for complying with section 7.5 of 327 IAC 15-5. The notice must inform the individual lot owners of the requirements to:
(1) install and maintain appropriate measures to prevent sediment from leaving the individual building lot; and
(2) maintain all erosion and sediment control measures that are to remain on-site as part of the construction plan.

PROJECT SITE OWNER RESPONSIBILITY STATEMENT

By signing this "Notice of Termination" letter, I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Printed name of project site owner ______________________________

Signature of project site owner ______________________________ **Date** *(month, day , year)* ______________

This "Notice of Termination" must be signed by an individual meeting the signatory requirements in 327 IAC 15-4-3(g).

The submittal of a Notice of Termination requires an original (wet ink) signature; a fax or photocopies are not acceptable.

SUBMITTAL OF THE "NOTICE OF TERMINATION"

Please submit the completed "Notice of Termination" to the Indiana Department of Environmental Management (IDEM). The submittal to IDEM must be an original signature; a fax or photocopies are not acceptable. A copy of the "Notice of Termination" is required to also be submitted to the Soil and Water Conservation District (SWCD) or a Municipal Separate Storm Sewer System (MS4). The appropriate entity will typically be the agency that reviewed the construction/storm water pollution prevention plan associated with the project. The "Notice of Termination" shall be mailed to the IDEM at

Indiana Department of Environmental Management
Storm Water Permits Coordinator
100 North Senate Avenue
Room 1255
Indianapolis, IN 46204-2251

Additional considerations

It is not required by 327 IAC 15-5 that the termination is verified prior to submittal, however the SWCD or MS4, as the plan review agency, may elect to field verify project completion prior to the "Notice of Termination" submittal. Several MS4s require (by local ordinance) approval of all terminations prior to submitting the "Notice of Termination" to IDEM. Failure to submit this document to an MS4 that has adopted this provision may be a violation of the local MS4 ordinance.

If the agency participates, submit the completed Notice of Termination form to the SWCD or MS4. The request for termination will be reviewed for concurrence and either returned to the project site owner for submittal to IDEM or forwarded to IDEM on behalf of the project site owner.

FOR AGENCY USE ONLY (FIELD VERIFICATION OF TERMINATION)

The SWCD, an MS4 entity, or the Indiana Department of Environmental Management may inspect the project site to evaluate the adequacy of the remaining storm water quality measures and compliance with the Notice of Termination (NOT) requirements. If the inspecting entity finds that the project site owner has met the requirements of 327 IAC 15-5-8, the entity may elect to sign off on the project. It is the responsibility of the project site owner to file the NOT with the Indiana Department of Environmental Management.

☐ **Accepted** The site referenced above has been inspected and it has been determined that the request to terminate this project is compliant with the requirements of 327 IAC 15-5. This form must be submitted to the IDEM for final processing.

☐ **Denied** The site referenced above has been inspected and it has been determined that the request to terminate this project is not compliant with the requirements of 327 IAC 15-5. Continue to implement the Storm Water Pollution Prevention Plan and take appropriate measures to minimize the discharge of pollutants.

Signature	**Printed name**	**Agency**	**Date** *(month, day , year)*

NOTICE OF TERMINATION INSPECTION
(To be Completed by the City of Fishers Surveyor or Agent)

All construction sites shall undergo a final inspection by the City Director of Public Works following submittal of a Notice of Termination (NOT) by the project owner to ensure the site is stabilized and that post construction BMPs have been properly installed.

Yes	No	N/A	
			1. Have all earth disturbing activities been completed?
			2. Are all soils stabilized with either vegetation or mulch?
			3. Are all drainageways stabilized with either vegetation, rip rap, or other armament?
			4. Have all temporary erosion and sediment control measures been removed?
			5. Has all construction waste, trash, and debris been removed from the site?
			6. Have all permanent stormwater quality BMPs been installed in accordance with the plans, specifications, and details?
			7. Are all permanent BMPs free of sediment accumulation resulting from construction activities?

If you answered "no" to any of the above questions, describe any corrective action which must be taken to remedy the problem and when the corrective actions are to be completed.

B4 – Individual Residential Lot Permit Forms

Instructions for Residential Lot Plot Plan Permit Request
Residential Lot Plot Plan Permit Request Application
Individual Lot Typical Erosion & Sediment Control Plan and Certification

INSTRUCTIONS FOR RESIDENTIAL LOT PLOT PLAN PERMIT REQUEST

1. Request shall be made to the City Community Development Department or Permitting and Inspections Department.
2. Request shall be made on standard form only, supplied by the Surveyor's Office.
3. The form shall be completely filled out, including the following information:
   a. Name of subdivision/minor plat and lot number.
   b. Section/Township/Range
   c. Parcel number of property involved.
   d. Project name (if none then put individual's name).
   e. Contact person(s).
   f. Type of residential lot and/or improvement. This office may require more details depending on the type of improvements being proposed.
4. A certified Plot Plan, including site layout (per Article 6, Section 6.04 of the Stormwater Management Resolution), is required to be submitted with each permit application.
5. An erosion and sediment control plan is required to be submitted with each permit application. This plan must conform to the minimum requirements in Article 6, Section 6.04. of the Stormwater Management Resolution.
6. Need to provide the name, address telephone number, and list of qualifications of the trained individual in charge of the mandatory stormwater pollution prevention self-monitoring program for the project site.
7. Need to abide by any additional requirements set forth in Article 6, Section 6.04, of the City of Fishers Stormwater Management Resolution.
8. The applicant or an agent of the applicant must sign the form.
9. Check or money order is to be made payable to the **City of Fishers**. The correct amount of fee, based on the Fee Ordinance, must be included with the application package.

RESIDENTIAL LOT PLOT PLAN PERMIT REQUEST

Name of Subdivision/Minor Plat & Lot #: ________________________________

Parcel Number: ______________________

Project Name: ____________________

Section/Township/Range ____________

Township Name: __________________

Applicant's Name: ___________________

Address: ____________________________

____

Phone: (___)________________________

Fax: (___)___________________________

Property Owner: __________________

Property Address: _________________

____

Phone: (___)_____________________

Fax: (___)_______________________

Contractor/Builder: ____

Address: ____

Phone: (___)__________________________ Fax: (___)_________________________

Contact Person: ______________________ Cell Phone: ______________________

Type of Residential Lot or Improvement: ______________________________________

Trained Individual in Charge of the Mandatory Stormwater Pollution Prevention Program

Name:______________ Address:________________________ Phone #:_________

List of Qualifications): ____

____

____

____

The individual lot operator is responsible for installation and maintenance of all erosion and sediment control measures until the site is stabilized.

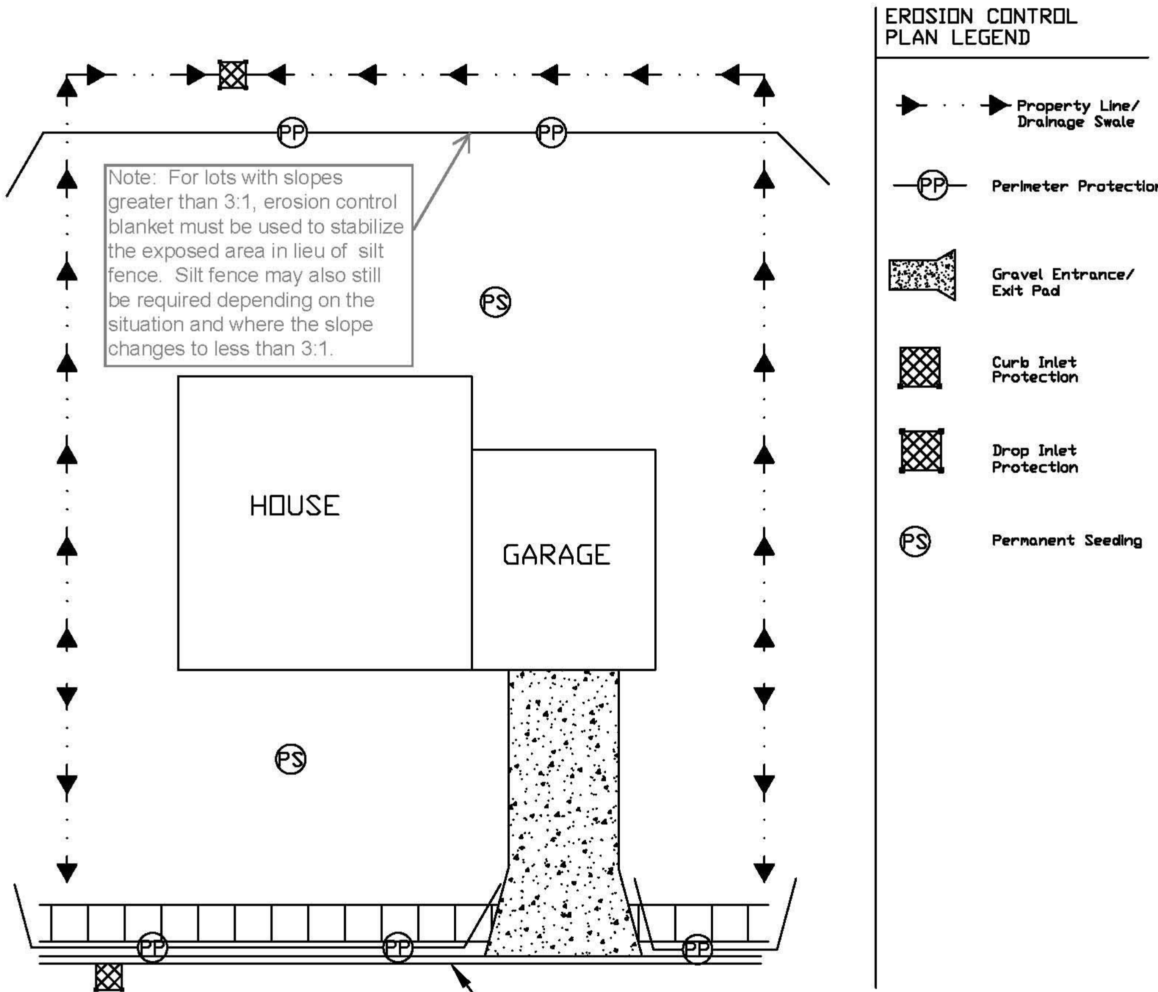
________________________________ ________________________

Signature Date

Check Title: Owner _____ Contractor _____ Engineer _____ Agent _____ Other ______

*** **For Office Use Only** *** Engineering Firm: __________________________

Permit # ________________ Plan Project # ________________ Check # _____



NOTES:

1. EROSION/SEDIMENT CONTROL MEASURES MUST BE FUNCTIONAL AND BE MAINTAINED THROUGHOUT CONSTRUCTION.
2. MAINTAIN POSITIVE DRAINAGE AWAY FROM THE STRUCTURE(S).
3. PERMANENT SEEDING AREAS TO BE TOP-SOILED, SEEDED, AND MULCHED BY OWNER AT COMPLETION OF CONSTRUCTION.

No	Date	Revisions

Town of Fishers

Department of Public Works/Engineering

Sample Erosion/Sediment Control Practice Plan for a Typical One- or Two-Family Dwelling Under Construction

Date: 17Feb04		Drawn By: JRH
Scale: NTS		Sheet: 1 of 1
File Name: Sample Erosion Control Detail.dwg		

APPENDIX C

CONSTRUCTION BMPs

BMP CN – 101
WHEEL WASH

DESCRIPTION

When a stabilized construction entrance is not preventing sediment from being tracked onto pavement, a wheel wash may be installed. Wheel washing is generally an effective BMP when installed with careful attention to topography. For example, a wheel wash can be detrimental if installed at the top of a slope abutting a right-of-way where the water from the dripping truck can run unimpeded into the street. Pressure washing combined with an adequately sized and surfaced pad with direct drainage to a large 10-foot x 10-foot sump can be very effective.

ADVANTAGES

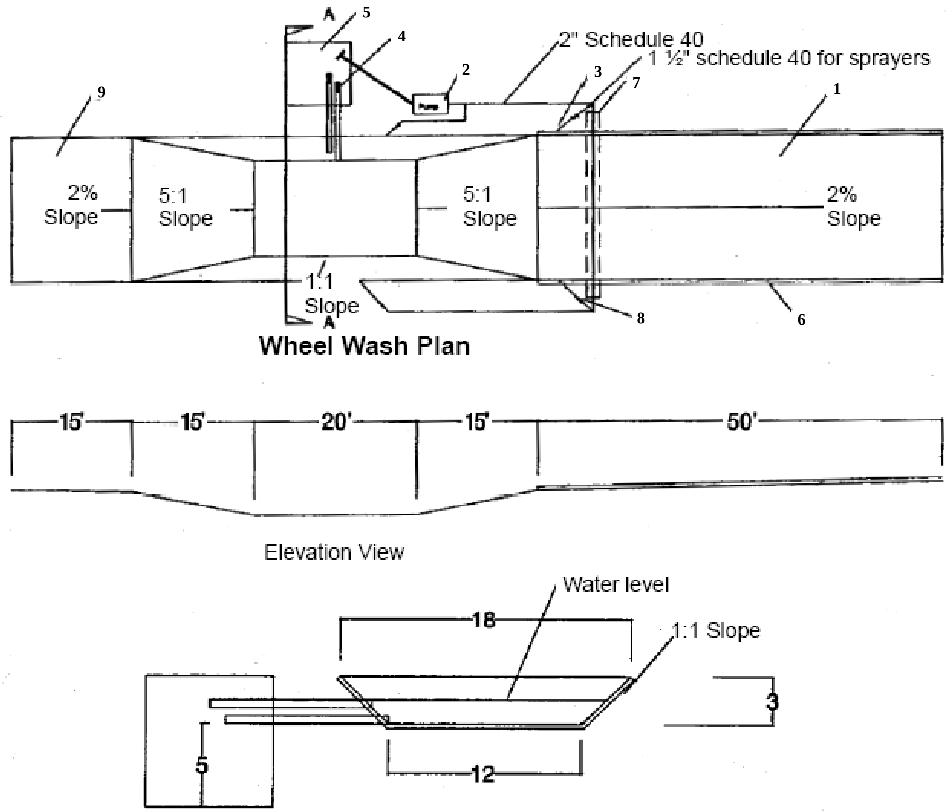
1. Wheel washes reduce the amount of sediment transported onto paved roads by motor vehicles.

DESIGN CRITERIA

1. Suggested details are shown in Figure CN-101-A. The City may allow other designs.
2. A minimum of 6 inches of asphalt treated base (ATB) over crushed base material or 8 inches over a good subgrade is recommended to pave the wheel wash.
3. Use a low clearance truck to test the wheel wash before paving. Either a belly dump or lowboy will work well to test clearance.
4. Keep the water level from 12 to 14 inches deep to avoid damage to truck hubs and filling the truck tongues with water.
5. Midpoint spray nozzles are only needed in extremely muddy conditions.
6. Wheel wash systems should be designed with a small grade change, 6 to 12 inches for a 10-foot-wide pond, to allow sediment to flow to the low side of pond to help prevent re-suspension of sediment.
7. A drainpipe with a 2- to 3-foot riser should be installed on the low side of the pond to allow for easy cleaning and refilling.
8. Polymers may be used to promote coagulation and flocculation in a closed-loop system. Polyacrylamide (PAM) added to the wheel wash water at a rate of 0.25 - 0.5 pounds per 1,000 gallons of water increases effectiveness and reduces cleanup time.
9. If PAM is already being used for dust or erosion control and is being applied by a water truck, the same truck can be used to change the wash water.
10. The wheel wash should start out the day with fresh water. The wash water should be changed a minimum of once per day.
11. On large earthwork jobs where more than 10-20 trucks per hour are expected, the wash water will need to be changed more often.
12. Wheel wash or tire bath wastewater shall be discharged to a separate on-site treatment system, such as closed-loop recirculation or land application, or to the sanitary sewer with proper local sewer utility approval.

REFERENCE

City of Tacoma, Surface Water Management Manual, 2003 or later



Section A-A
NTS

Notes:

1. Asphalt construction entrance 6 in. asphalt treated base (ATB).
2. 3-inch trash pump with floats on the suction hose.
3. Midpoint spray nozzles, if needed.
4. 6-inch sewer pipe with butterfly valves. Bottom one is a drain. Locate top pipe's invert 1 foot above bottom of wheel wash.
5. 8 foot x 8 foot sump with 5 feet of catch. Build so can be cleaned with trackhoe.
6. Asphalt curb on the low road side to direct water back to pond.
7. 6-inch sleeve under road.
8. Ball valves.
9. 15 foot. ATB apron to protect ground from splashing water.

Figure CN-101-A

BMP CN – 102
DEWATERING STRUCTURE

DESCRIPTION

Water which is pumped from a construction site usually contains a large amount of sediment. A dewatering structure is designed to remove the sediment before water is released off-site.

This practice includes several types of dewatering structures which have different applications dependent upon site conditions and types of operation. Other innovative techniques for accomplishing the same purpose are encouraged, but only after specific plans and details are submitted to and approved by the City.

DESIGN CRITERIA

1. A dewatering structure must be sized (and operated) to allow pumped water to flow through the filtering device without overtopping the structure.
2. Material from any required excavation shall be stored in an area and protected in a manner that will prevent sediments from eroding and moving off-site.
3. An excavated basin (applicable to “Straw Bale/Silt Fence Pit”) may be lined with filter fabric to help reduce scour and to prevent the inclusion of soil from within the structure.
4. Design criteria more specific to each particular dewatering device can be found in Figures CN-102-A through CN-102-C.
5. A dewatering structure may not be needed if there is a well-stabilized, vegetated area onsite to which water may be discharged. The area must be stabilized so that it can filter sediment and at the same time withstand the velocity of the discharged water without eroding. A minimum filtering length of 75 feet must be available in order for such a method to be feasible.
6. The filtering devices must be inspected frequently and repaired or replaced once the sediment build-up prevents the structure from functioning as designed.
7. The accumulated sediment which is removed from a dewatering device must be spread on-site and stabilized or disposed of at an approved disposal site as per approved plan.

   <u>Portable Sediment Tank (see Figure CN102-A)</u>

   - The structure may be constructed with steel drums, sturdy wood or other material suitable for handling the pressure exerted by the volume of water.
   - Sediment tanks will have a minimum depth of 2 ft.
   - The sediment tank shall be located for easy clean-out and disposal of the trapped sediment and to minimize the interference with construction activities.
   - The following formula shall be used to determine the storage volume of the sediment tank:

     Pump discharge (gallons/min.) x 16 = cubic feet of storage required

   - Once the water level nears the top of the tank, the pump must be shut off while the tank drains and additional capacity is made available.
   - The tank shall be designed to allow for emergency flow over top of the tank. Clean-out of the tank is required once one-third of the original capacity is depleted due to sediment accumulation. The tank shall be clearly marked showing the clean-out point.

Filter Box (see Figure CN-102-B)

- The box selected should be made of steel, sturdy wood or other materials suitable to handle the pressure requirements imposed by the volume of water. Normally readily available 55 gallon drums welded top to bottom will suffice in most cases.
- Bottom of the box shall be made porous by drilling holes (or some other method).
- Coarse aggregate shall be placed over the holes at a minimum depth of 12 inches, metal “hardware” cloth may need to be placed between the aggregate and the holes if holes are drilled larger than the majority of the stone.
- As a result of the fast rate of flow of sediment-laden water through the aggregate, the effluent must be directed over a well-vegetated strip of at least 50 feet after leaving the base of the filter box.
- The box shall be sized as follows:

  Pump discharge (gallons/min.) x 16 = cubic feet of storage required

- Once the water level nears the top of the box, the pump must be shut off while the box drains and additional capacity is made available.
- The box shall be designed/constructed to allow for emergency flow over the top of this box.
- Clean-out of the box is required once one-third of the original capacity is depleted due to sediment accumulation. The tank shall be clearly marked showing the clean-out point.
- If the stone filter does become clogged with sediment so that it no longer adequately performs its function, the stones must be pulled away from the inlet, cleaned and replaced.
- Using a filter box only allows for minimal settling time for sediment particles; therefore, it should only be used when site conditions restrict the use of the other methods.

Straw Bale/Silt Fence Pit (see Figure CN-102-C)

- Measure shall consist of straw bales, silt fence, a stone outlet (a combination of riprap and aggregate) and a wet storage pit oriented as shown in Figure CN-102-C.
- The structure must have a capacity which is dictated by the following formula:

  Pump discharge (gallons/min.) x 16 = cubic feet of storage required

- In calculating the capacity, one should include the volume available from the floor of the excavation to the crest of the stone weir.
- In any case, the excavated area should be a minimum of 3 feet below the base of the perimeter measures (straw bales or silt fence).
- The perimeter measures must be installed as per the guidelines found in BMP-4, STRAW BALE BARRIER and BMP-5, SILT FENCE.
- Once the water level nears the crest of the stone weir (emergency overflow), the pump must be shut off while the structure drains down to the elevation of the wet storage.
- The wet storage pit may be dewatered only after a minimum of 6 hours of sediment settling time. This effluent should be pumped across a well vegetated area or through a silt fence prior to entering a watercourse.
- Once the wet storage area becomes filled to one-half of the, excavated depth, accumulated sediment shall be removed and properly disposed of.

- Once the device has been removed, ground contours will be returned to original condition.

REFERENCE

United States Army Corps of Engineers, Handbook for the Preparation of Storm Water Pollution Prevention Plans for Construction Activities, 1997 or later

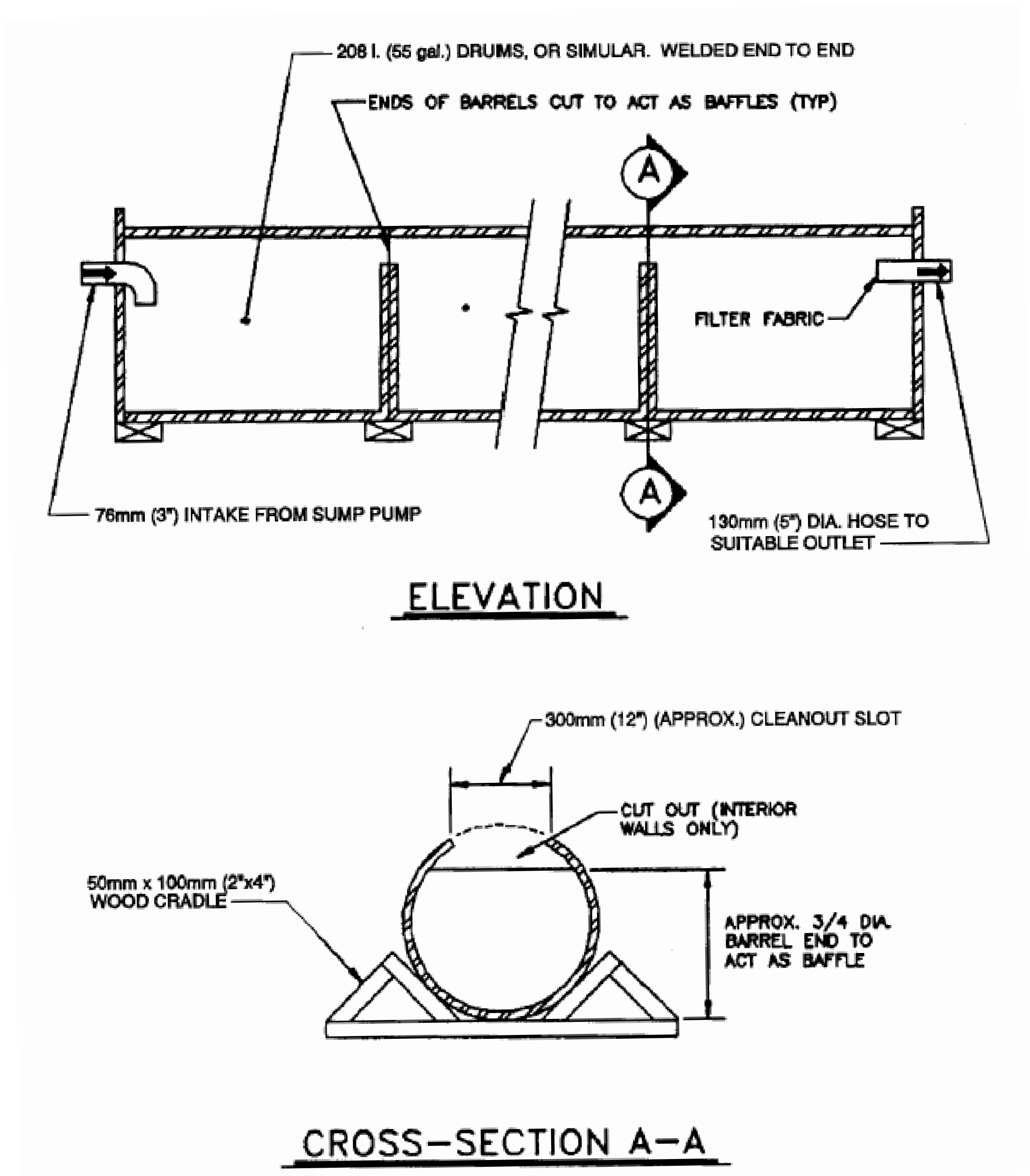


Figure CN-102-A
Portable Sediment Tank

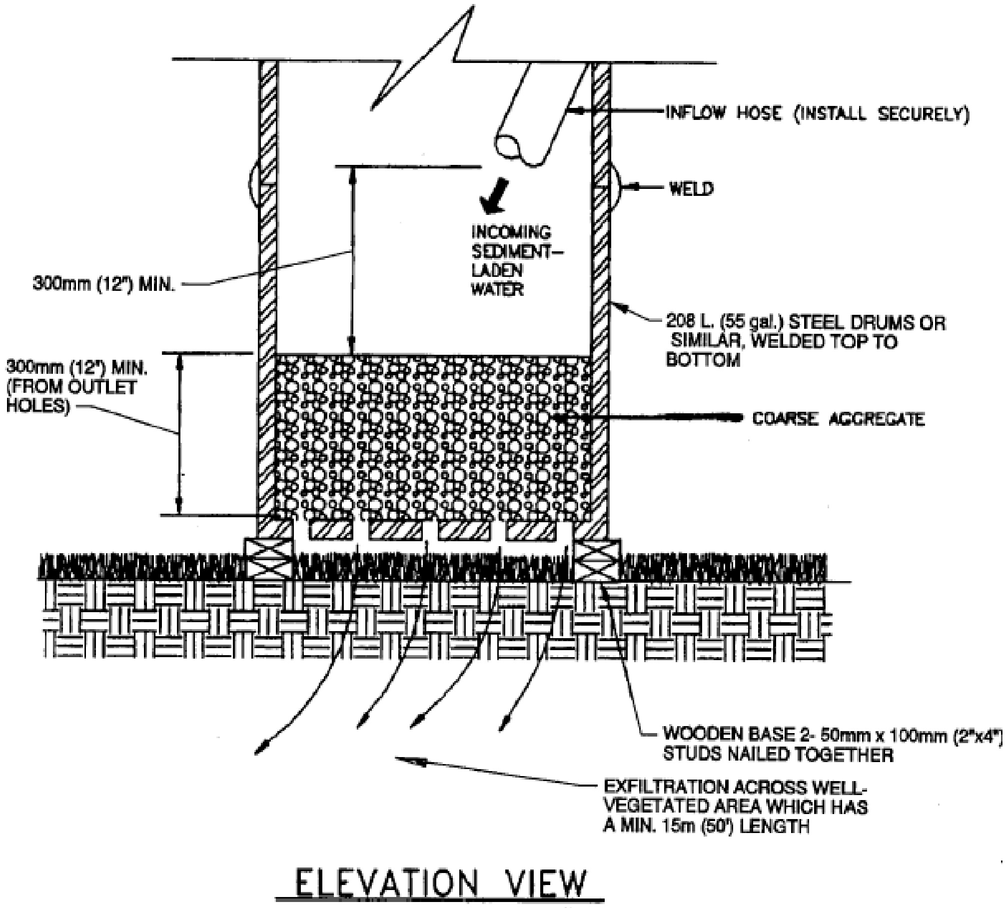


Figure CN-102-B
Filter Box

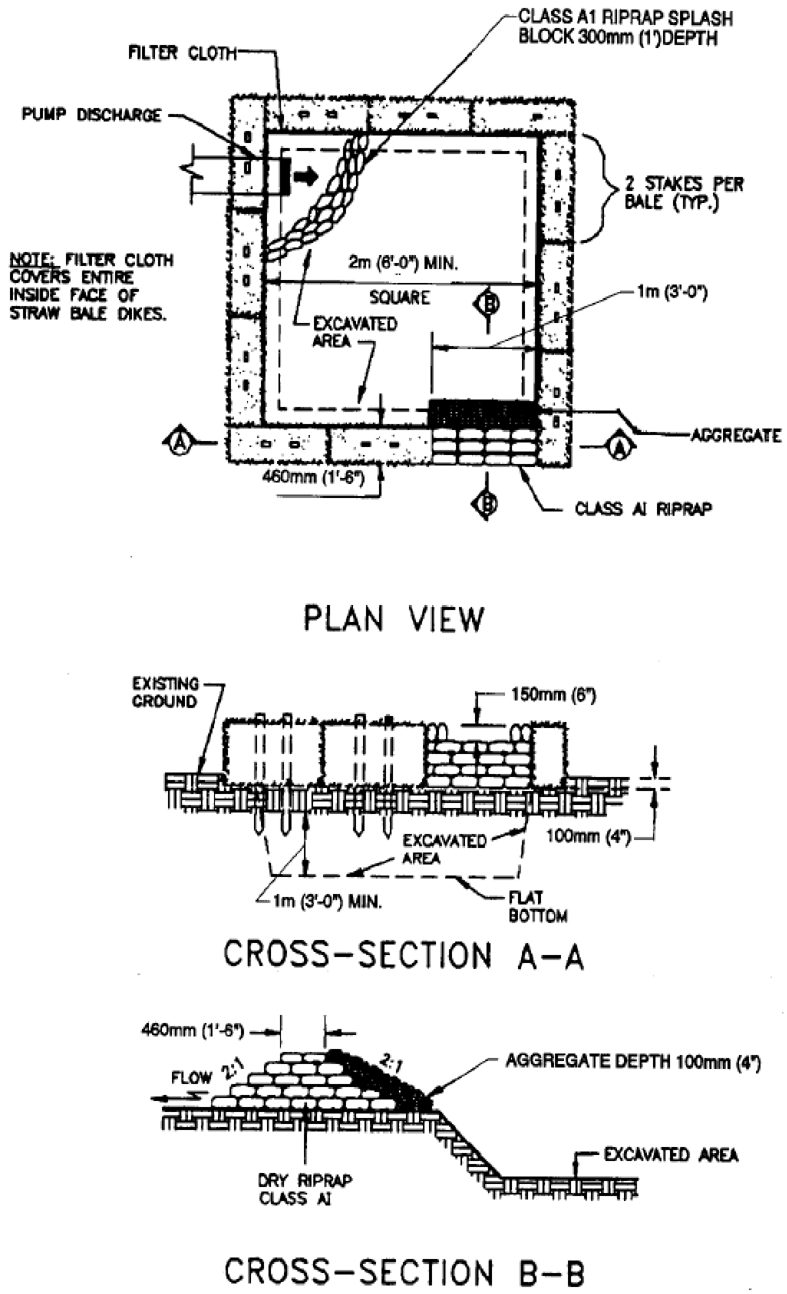


Figure CN-102-C
Straw Bale/Silt Fence Pit

BMP CN – 103
SPILL PREVENTION AND CONTROL

DESCRIPTION

These procedures and practices are implemented to prevent and control spills in a manner that minimizes or prevents the discharge of spilled material to the drainage system or watercourses.

This best management practice (BMP) applies to all construction projects. Spill control procedures are implemented anytime chemicals and/or hazardous substances are stored. Substances may include, but are not limited to:

- Soil stabilizers/binders
- Dust Palliatives
- Herbicides
- Growth inhibitors
- Fertilizers
- Deicing/anti-icing chemicals
- Fuels
- Lubricants
- Other petroleum distillates

To the extent that the work can be accomplished safely, spills of oil, petroleum products, sanitary and septic wastes, and substances listed under 40 Code of Federal Regulations (CFR) parts 110, 117, and 302 shall be contained and cleaned up immediately.

LIMITATIONS

1. This BMP only applies to spills caused by the contractor.
2. Procedures and practices presented in this BMP are general. Contractor shall identify appropriate practices for the specific materials used or stored on-site in advance of their arrival at the site.

DESIGN CRITERIA

1. To the extent that it doesn't compromise clean up activities, spills shall be covered and protected from stormwater runoff during rainfall.
2. Spills shall not be buried or washed with water.
3. Used clean up materials, contaminated materials, and recovered spill material that is no longer suitable for the intended purpose shall be stored and disposed of in conformance with BMP CN-105: Hazardous Waste Management.
4. Water used for cleaning and decontamination shall not be allowed to enter storm drains or watercourses and shall be collected and disposed of in accordance with BMP CN-105: Hazardous Waste Management.
5. Water overflow or minor water spillage shall be contained and shall not be allowed to discharge into drainage facilities or watercourses.

6. Proper storage, clean-up and spill reporting instruction for hazardous materials stored or used on the project site shall be posted at all times in an open, conspicuous and accessible location.
7. Waste storage areas shall be kept clean, well organized and equipped with ample clean-up supplies as appropriate for the materials being stored. Perimeter controls, containment structures, covers and liners shall be repaired or replaced as needed to maintain proper function.
8. Verify weekly that spill control and clean up materials are located near material storage, unloading, and use areas.
9. Update spill prevention and control plans and stock appropriate clean-up materials whenever changes occur in the types of chemicals used or stored onsite.

<u>Cleanup and Storage Procedures for Minor Spills</u>

- Minor spills typically involve small quantities of oil, gasoline, paint, etc., which can be controlled by the first responder at the discovery of the spill.
- Use absorbent materials on small spills rather than hosing down or burying the spill.
- Remove the absorbent materials promptly and dispose of properly.
- The practice commonly followed for a minor spill is:
    - Contain the spread of the spill.
    - Recover spilled materials.
    - Clean the contaminated area and/or properly dispose of contaminated materials.

<u>Cleanup and Storage Procedures for Semi-Significant Spills</u>

- Semi-significant spills still can be controlled by the first responder along with the aid of other personnel such as laborers and the foreman, etc. This response may require the cessation of all other activities.
- Clean up spills immediately:
- Notify the project foreman immediately. The foreman shall notify the applicable Emergency Management Agency’s Hazardous Materials Response Team.
- Contain spread of the spill.
- If the spill occurs on paved or impermeable surfaces, clean up using "dry" methods (absorbent materials, cat litter and/or rags). Contain the spill by encircling with absorbent materials and do not let the spill spread widely.
- If the spill occurs in dirt areas, immediately contain the spill by constructing an earthen dike. Dig up and properly dispose of contaminated soil.
- If the spill occurs during rain, cover spill with tarps or other material to prevent contaminating runoff.

<u>Cleanup and Storage Procedures for Significant/Hazardous Spills</u>

- For significant or hazardous spills that cannot be controlled by personnel in the immediate vicinity, notify the local emergency response by dialing 911. In addition to 911, the contractor will notify the proper City officials. It is the contractor's responsibility to have all emergency phone numbers at the construction site.

- For spills of federal reportable quantities, in conformance with the requirements in 40 CFR parts 110,119, and 302, the contractor shall notify the National Response Center at (800) 424-8802.
- Notification shall first be made by telephone and followed up with a written report.
- The services of a spills contractor or a Haz-Mat team shall be obtained immediately. Construction personnel shall not attempt to clean up the spill until the appropriate and qualified personnel have arrived at the job site.

REFERENCE

California Department of Transportation, Construction Site BMP Manual, 2000 or later

BMP CN – 104
SOLID WASTE MANAGEMENT

DESCRIPTION

Solid waste management procedures and practices are designed to minimize or eliminate the discharge of pollutants to the drainage system or to watercourses as a result of the creation, stockpiling, or removal of construction site wastes.

Solid waste management procedures and practices are implemented on all construction projects that generate solid wastes.

Solid wastes include but are not limited to:

1. Construction wastes including brick, mortar, timber, steel and metal scraps, sawdust, pipe and electrical cuttings, non-hazardous equipment parts, styrofoam and other materials used to transport and package construction materials.
2. Landscaping wastes, including vegetative material, plant containers, and packaging materials.
3. Litter, including food containers, beverage cans, coffee cups, paper bags, plastic wrappers, and smoking materials, including litter generated by the public.

LIMITATIONS

1. Temporary stockpiling of certain construction wastes may not necessitate stringent drainage related controls during the non-rainy season.

DESIGN CRITERIA

1. Dumpsters of sufficient size and number shall be provided to contain the solid waste generated by the project and properly serviced.
2. Littering on the project site shall be prohibited.
3. To prevent clogging of the storm drainage system, litter and debris removal from drainage grates, trash racks, and ditch lines shall be a priority.
4. Trash receptacles with lids shall be provided in the contractor's yard, field trailer areas, and at locations where workers congregate for lunch and break periods.
5. Construction debris and litter from work areas within the construction limits of the project site shall be collected and placed in watertight dumpsters at least weekly regardless of whether the litter was generated by the contractor, the public, or others. Collected litter and debris shall not be placed in or next to drain inlets, storm water drainage systems or watercourses.
6. Full dumpsters shall be removed from the project site and the contents shall be disposed of, off-site, in an appropriate manner.;
7. Litter stored in collection areas and containers shall be handled and disposed of by trash hauling contractors.
8. Construction debris and waste shall be removed from the site every two weeks.
9. Stormwater run-off shall be prevented from contacting stored solid waste through the use of berms, dikes, or other temporary diversion structures or through the use of measures to elevate waste from site surfaces.
10. Solid waste storage areas shall be located at least 50 ft from drainage facilities and watercourses and shall not be located in areas prone to flooding or ponding.

11. Except during fair weather, construction and landscaping waste not stored in watertight dumpsters shall be securely covered from wind and rain by covering the waste with tarps, plastic sheeting, or equivalent.
12. Dumpster washout on the project site is not allowed.
13. Notify trash hauling contractors that only watertight dumpsters are acceptable for use on-site.
14. Plan for additional containers during the demolition phase of construction.
15. Plan for more frequent pickup during the demolition phase of construction.
16. Construction waste shall be stored in a designated area. Access to the designated area shall either be well vegetated ground, a concrete or asphalt road or drive, or a gravel construction entrance, to avoid mud tracking by trash hauling contractors.
17. Segregate potentially hazardous waste from non-hazardous construction site waste.
18. Keep the site clean of litter debris.
19. Make sure that toxic liquid wastes (e.g., used oils, solvents, and paints) and chemicals (e.g., acids, pesticides, additives, curing compounds) are not disposed of in dumpsters designated for construction debris.
20. For disposal of hazardous waste, see BMP CN-105: Hazardous Waste Management. Have hazardous waste hauled to an appropriate disposal and/or recycling facility.
21. Salvage or recycle useful vegetation debris, packaging and/or surplus building materials when practical. For example, trees and shrubs from land clearing can be converted into wood chips, then used as mulch on graded areas. Wood pallets, cardboard boxes, and construction scraps can also be recycled.
22. Prohibit littering by employees, subcontractors, and visitors.
23. Wherever possible, minimize production of solid waste materials.

REFERENCE

California Department of Transportation, Construction Site BMP Manual, 2000 or later

BMP CN – 105
HAZARDOUS WASTE MANAGEMENT

DESCRIPTION

These are procedures and practices to minimize or eliminate the discharge of pollutants from construction site hazardous waste to the storm drain systems or to watercourses.

This best management practice (BMP) applies to all construction projects.

Hazardous waste management practices are implemented on construction projects that generate waste from the use of:

- Petroleum Products,
- Asphalt Products,
- Concrete Curing Compounds,
- Pesticides,
- Acids,
- Paints,
- Stains,
- Solvents,
- Wood Preservatives,
- Roofing Tar, or
- Any materials deemed a hazardous waste in 40 CFR Parts 110, 117, 261, or 302.

DESIGN CRITERIA

<u>Storage Procedures</u>

1. Wastes shall be stored in sealed containers constructed of a suitable material and shall be labeled as required by 49 CFR Parts 172,173, 178, and 179.
2. All hazardous waste shall be stored, transported, and disposed as required in 49 CFR 261-263.
3. Waste containers shall be stored in temporary containment facilities that shall comply with the following requirements:
   - Temporary containment facility shall provide for a spill containment volume able to contain precipitation from a 24-hour, 25 year storm event, plus the greater of 10% of the aggregate volume of all containers or 100% of the capacity of the largest tank within its boundary, whichever is greater.
   - Temporary containment facility shall be impervious to the materials stored there for a minimum contact time of 72 hours.
   - Temporary containment facilities shall be maintained free of accumulated rainwater and spills. In the event of spills or leaks accumulated rainwater and spills shall be placed into drums after each rainfall. These liquids shall be handled as a hazardous waste unless testing determines them to be non-hazardous. Non-hazardous liquids shall be sent to an approved disposal site.
   - Sufficient separation shall be provided between stored containers to allow for spill cleanup and emergency response access.
   - Incompatible materials, such as chlorine and ammonia, shall not be stored in the same temporary containment facility.

- Throughout the rainy season, temporary containment facilities shall be covered during non-working days, and prior to rain events. Covered facilities may include use of plastic tarps for small facilities or constructed roofs with overhangs. A storage facility having a solid cover and sides is preferred to a temporary tarp. Storage facilities shall be equipped with adequate ventilation.

4. Drums shall not be overfilled and wastes shall not be mixed.
5. Unless watertight, containers of dry waste shall be stored on pallets.
6. Paint brushes and equipment for water and oil based paints shall be cleaned within a contained area and shall not be allowed to contaminate site soils, watercourses or drainage systems. Waste paints, thinners, solvents, residues, and sludge that cannot be recycled or reused shall be disposed of as hazardous waste. When thoroughly dry, latex paint and paint cans, used brushes, rags, absorbent materials, and drop cloths shall be disposed of as solid waste.
7. Ensure that adequate hazardous waste storage volume is available.
8. Ensure that hazardous waste collection containers are conveniently located.
9. Designate hazardous waste storage areas on site away from storm drains or watercourses and away from moving vehicles and equipment to prevent accidental spills.
10. Minimize production or generation of hazardous materials and hazardous waste on the job site.
11. Use containment berms in fueling and maintenance areas and where the potential for spills is high.
12. Segregate potentially hazardous waste from non-hazardous construction site debris.
13. Keep liquid or semi-liquid hazardous waste in appropriate containers (closed drums or similar) and under cover.
14. Clearly label all hazardous waste containers with the waste being stored and the date of accumulation.
15. Place hazardous waste containers in secondary containment.
16. Do not allow potentially hazardous waste materials to accumulate on the ground.
17. Do not mix wastes.

Disposal Procedures

1. Waste shall be removed from the site within 90 days of being generated.
2. Waste shall be disposed of by a licensed hazardous waste transporter at an authorized and licensed disposal facility or recycling facility utilizing properly completed Uniform Hazardous Waste Manifest forms.
3. A certified laboratory shall sample waste and classify it to determine the appropriate disposal facility.
4. Make sure that toxic liquid wastes (e.g., used oils, solvents, and paints) and chemicals (e.g., acids, pesticides, additives, curing compounds) are not disposed of in dumpsters designated for solid waste construction debris.
5. Properly dispose of rainwater in secondary containment that may have mixed with hazardous waste.
6. Recycle any useful material such as used oil or water-based paint when practical.

Maintenance and Inspection

1. A foreman and/or construction supervisor shall monitor on-site hazardous waste storage and disposal procedures.
2. Waste storage areas shall be kept clean, well organized, and equipped with ample clean-up supplies as appropriate for the materials being stored. Storage areas shall be inspected in conformance with the provisions in the contract documents.

3. Perimeter controls, containment structures, covers, and liners shall be repaired or replaced as needed to maintain proper function.
4. Hazardous spills shall be cleaned up and reported in conformance with the applicable Material Safety Data Sheet (MSDS) and the instructions posted at the project site.
5. The National Response Center, at (800) 424-8802, shall be notified of spills of Federal reportable quantities in conformance with the requirements in 40 CFR parts 110, 117, and 302.
6. Copy of the hazardous waste manifests shall be provided to the owner.

REFERENCE

California Department of Transportation, Construction Site BMP Manual, 2000 or later

APPENDIX D

POST-CONSTRUCTION APPENDICES

Wetland Operation, Maintenance, and Management Inspection Checklist

Project: ______________________________
Location: ______________________________
Date: ____________________ **GISOBJID:** ____________________
Inspector: ____________________ **Title:** ____________________
Signature: ____________________ **Info:** ____________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
1. Embankment and Emergency Spillway		
Healthy vegetation with at least 85% ground cover.		
No signs of erosion on embankment.		
No animal burrows.		
Embankment is free of cracking, bulging, or sliding.		
Embankment is free of woody vegetation.		
Embankment is free of leaks or seeps		
Emergency spillway is clear of obstructions.		
2. Riser and Principal Spillway		
Low flow outlet free of obstruction.		
Trash rack is not blocked or damaged.		
Riser is free of excessive sediment buildup		
Outlet pipe is in good condition.		
Control valve is operational		

Outfall channels are stable and free of scouring.		
3. Wetland		
Plants covering greater than 85% of total wetland surface area (excluding open water areas)		
Observed plant types consistent with accepted plans		
No evidence of excessive sediment accumulation in wetland area		
Water depths consistent with accepted plans		
No evidence of erosion on banks.		
Wetland areas clean of debris (litter, branches, etc.)		
No evidence of dumping of yard wastes into BMP		
4. Forebay		
Sediment is being collected by forebay(s)		
Forebay is not in need of cleanout (less than 50% full)		

Actions to be Taken:____

Media Filtration or Swirl Concentrator Operation, Maintenance, and Management Inspection Checklist

Project: ____
Location: ____
Date: ______________________________ **GISOBID:** ____________________
Inspector: ______________________________ **Title:** ____________________
Signature: ______________________________ **Info:** ____________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
1. Debris Cleanout		
Drainage overflow mechanism open for flow and not damaged		
Filtration cylinder or bag clean of debris and sediment		
Inlet and outlets clear of debris and sediment		
2. Oil and Grease		
No evidence of filter surface clogging		
Oil and grease sponge installed, visible, and clean (not all black)		
3. Debris Filter Bag, Basket Frame, or Diversion Structure		
Filter bag in good condition with no tears		
Frame securely attached to the storm drain structure		
Diversion weir operational and not damaged		
4. Water Retention Where Required		
Water holding chambers at normal pool		
No evidence of leakage		

Actions to be Taken: ____

Filter Strip Operation, Maintenance, and Management Inspection Checklist

Project:____
Location:____
Date: ______________________ **GISOBJID:**______________
Inspector:____________________ **Title:**________________
Signature:____________________ **Info:**________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
1. Vegetation		
Observed plant types consistent with accepted plans		
Vegetation is healthy		
Plants covering greater than 85% of total BMP surface area		
Grass height not more than 6 inches		
No evidence of concentrated flows		
No evidence of erosion		
2. Level Spreader		
Lip of spreader showing no signs of erosion		
Sediment noted in spreader?		

Actions to be Taken:____

Detention Pond Operation, Maintenance, and Management Inspection Checklist

Project:____
Location:____
Date: ______________________________________**GISOBJID:**__________________________
Inspector:______________________________________**Title:**__________________________________
Signature:______________________________________ **Info:**__________________________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
1. Embankment and emergency spillway		
Healthy vegetation with at least 85% ground cover.		
No signs of erosion on embankment.		
No animal burrows.		
Embankment is free of cracking, bulging, or sliding.		
Embankment is free of woody vegetation.		
Embankment is free of leaks or seeps		
Emergency spillway is clear of obstructions.		
Vertical/horizontal alignment of top of dam “As-Built”		
2. Riser and principal spillway		
Low flow outlet free of obstruction.		
Trash rack is not blocked or damaged.		
Riser is free of excessive sediment buildup		
Outlet pipe is in good condition.		
Control valve is operational		
Outfall channels are stable and free of scouring.		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
3. Permanent Pool (Wet Ponds)		
No Evidence of undesirable vegetation, algae, or larval growth		
No accumulation of floating or floatable debris or trash		
No evidence of shoreline scour or erosion		
4. Sedimentation		
Sediment is being collected by forebay(s)		
Forebay is not in need of cleanout (less than 50% full)		
Excessive pond sedimentation is evident		
5. Dry Pond Areas		
Healthy vegetation with at least 85% ground cover.		
No undesirable woody vegetation		
Low flow channels clear of obstructions		
No evidence of sediment and/or trash accumulation		
6. Condition of Outfall into Ponds		
No riprap failures		
No evidence of slope erosion or scouring		
Storm drain pipes are in good condition, with no evidence of non-stormwater discharges		
Endwalls/Headwalls are in good condition		

List of Post-Construction BMP Appendices

- **Stormwater BMP Fact Sheets (Appendix D1)**
  - **Part 1: Nonstructural BMPs for LID Approach**
  - **Part 2: Structural BMPs for LID and Conventional Approaches**
- **Recommended Plant Lists for Best Management Practices (Appendix D2)**
- **Recommended Materials (Appendix D3)**
- **Soil Infiltration Testing Protocol (Appendix D4)**
- **Maintenance Inspection Checklists (Appendix D5)**
- **Stormwater Management Practices Maintenance Agreement (Appendix D6)**

Stormwater BMP Fact Sheets

Appendix D1

Part 1

Nonstructural BMPs for LID Approach

INTRODUCTION TO LID NONSTRUCTURAL BEST MANAGEMENT PRACTICES

A core concept of LID is preventing stormwater runoff by integrating site design and planning techniques that preserve natural systems and hydrologic functions, protect open spaces, as well as conserve wetlands and stream corridors on a site. This introductory segment provides detailed technical information on integrating nonstructural Best Management Practices (BMPs) early into the site design process.

The nonstructural BMPs are:

- Cluster-Type development,
- Minimize soil compaction,
- Minimize total disturbed area,
- Protect natural flow pathways,
- Protect riparian buffers,
- Protect sensitive areas,
- Reduce impervious surfaces, and
- Stormwater disconnection.

Specifically, this introductory segment discusses:

- The benefits of using nonstructural BMPs,
- The process for selecting nonstructural BMPs, and
- An overview of the format and contents of BMP fact sheets.

Green Development Standards

The primary LID characteristic of nonstructural BMPs is preventing stormwater runoff from the site. This differs from the goal of structural BMPs which is to help mitigate stormwater-related impacts after they have occurred.

More specifically, nonstructural BMPs take broader planning and design approaches, which are less "structural" in their form. Many nonstructural BMPs apply to an entire site and often to an entire community, such as wetland protection through a community wetland ordinance. They are not fixed or specific to one location. Structural BMPs, on the other hand, are decidedly more location specific and explicit in their physical form.

Benefits of using nonstructural BMPs

There are numerous benefits of incorporating nonstructural BMPs into a site. While individual benefits are discussed in detail under each BMP, there are many benefits that apply to most, if not all, of the nonstructural BMPs. These include:

- Reduced land clearing costs,
- Reduced costs for total infrastructure,
- Reduced total stormwater management costs,
- Enhanced community and individual lot aesthetics, and
- Improved overall marketability and property values.

The following steps are used to integrate LID into the site design process:

Step 1 - Property acquisition and use analysis

Step 2 - Inventory and evaluate the site

Step 3 - Integrate municipal, county, state, and federal requirements

Step 4 - Develop initial concept design using nonstructural BMPs

Step 5 - Organize pre-submission meeting and site visit with local decision makers

Step 6 - Incorporate revisions to development concept

Step 7 - Apply structural BMP selection process

Step 8 - Apply the LID calculation methodology

Step 9 - Develop the preliminary site plan

BMP Selection Process

This introductory segment and the nonstructural BMP fact sheets that follow focus on Step 4 in the site design process for LID to develop the initial concept design using nonstructural BMPs. Selection of nonstructural BMPs should focus on information gathered in Steps 1-3 of the site design process. Following are specific questions and issues to provide guidance in the selection process.

- How is the property being used? A residential development may have more applicability for certain nonstructural BMPs than other land uses. For example, cluster development is an applicable BMP for residential development, but may be less used in more urban situations.

- What natural features are on site? A thorough site inventory will provide the necessary information to assess the ability to implement many of the BMPs, including preserving sensitive and riparian areas.

- What local, county, state, and other regulations need to be met? A review of local, county, state, and other regulations can also provide guidance on selecting the right mix of nonstructural BMPs.

Overview of the Format of the BMP Fact Sheets

Each BMP fact sheet begins with a summary sheet that provides a quick overview of the BMP. The ratings contained in the summary sheet have been condensed to general categories (High, Medium, and Low) with these summary ratings often discussed in more detail in the detailed information segment of the fact sheet. Stormwater Quality Functions are based on a compilation of recent national/international studies rating pollutant removal performance.

Following the summary sheet, a series of detailed information on the BMP is provided which includes:

Variations

Discusses the variations to the BMP, if applicable. Examples include alternatives in design that can increase storage capacity or infiltration rates.

Applications

Indicates land use types for which the BMP is applicable or feasible.

Design Considerations

This section includes a list of technical procedures to be considered when designing for the individual BMP. This specific design criteria is presented, which can assist planners in incorporating LID techniques into a site design, as well as provide a basis for reviewers to evaluate submitted LID techniques.

Stormwater Calculations and Functions

Provides specific guidance on achieving sizing criteria, volume reduction, and peak rate mitigation, as applicable. This section also references the Post-Construction Stormwater Quality Management Chapter of the Technical Standards which discusses in detail how to achieve a specific standard or implement measures that contribute to managing water onsite in a more qualitative manner.

Construction Guidelines

Provides a typical construction sequence for implementing the BMP. However, it does not specifically address soil erosion and sedimentation control procedures. Erosion and sediment control methods need to adhere to the construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM’s Soil Erosion and Sedimentation Control (Rule 5) Program.

Maintenance

Provides guidance on recommended maintenance procedures for the BMP.

Winter Considerations

Discusses how well the BMP performs in Indiana's cold climate.

Cost

Provides general cost information for comparison purposes. If specific dates of costs are not referenced in this section, the costs reflect 2007 conditions.

Designer/Reviewer's Checklist

Developed to assist a designer and or reviewer in evaluating the critical components of a BMP that is being designed. It references not only individual design considerations, but also suggests review of additional pertinent sections of the Technical Standards that may need to be considered for implementation of that BMP.

References

Provides a list of sources of information utilized in the creation of this section of the manual. This list also provides additional sources that can be used for additional information.

Each fact sheet includes a summary sheet and additional detailed information regarding the BMP:

BMP Fact Sheet

TITLE

Short definition of BMP

Applications – Indicates in what type of land use BMP is applicable or feasible (**Yes, No,** or **Limited**).

Stormwater Quantity Functions – Indicates how well the BMP functions in mitigating stormwater management criteria (**High, Medium,** or **Low**).

Stormwater Quality Functions – Indicates how well the BMP performs in terms of pollutant removal (**High, Medium,** or **Low**).

Applications		**Stormwater Quantity Functions**	
Residential		Volume	
Commercial		Groundwater Recharge	
Ultra Urban		Peak Rate	
Industrial		Stormwater Quality Functions	
Retrofit		TSS – Total Suspended Solids	
Highway/Road		TP – Total Phosphorus	
Recreational		TN or NO3 – Total Nitrogen/Nitrate	
		Temperature	

Variations (optional)

Lists of variations to the BMP if applicable

Key Design Features

Bulleted list of information that is key to the design of BMP

Site Factors (optional)

List of specific factors that relate to BMP performance

- Water table/bedrock separation distance
- Soil type
- Feasibility on steeper slopes
- Applicability on potential hotspots (e.g., brownfields)

Benefits

List of benefits directly related to implementing the BMP

Limitations

List of site constraints associated with implementation

Additional Considerations

Cost – Indicates whether cost is high, medium or low by the following categories

- **High** – adds more than 5% to total project cost
- **Medium –** adds 1–5% to total project cost
- **Low** – adds less than 1% to total project cost

Maintenance – Indicates level of maintenance required to maintain BMP (**High, Medium,** or **Low**).

- **High** – Maintenance intensive (i.e., year-round maintenance)
- **Medium** – Several times per year
- **Low** – One time per year

Winter Performance – Indicates if BMP provides equivalent performance throughout the winter (**High, Medium,** or **Low**)

- **High** – BMP performs very well in winter conditions
- **Medium** – BMP has reduced performance in winter conditions
- **Low** – BMP still performs in winter conditions, but performance is significantly reduced.

Detailed Information - As indicated earlier, more detailed information regarding each BMP, including Description and Function, Variations, Applications, Design Considerations, Stormwater Calculations and Functions, Construction Guidelines, Maintenance, Winter Considerations, Cost, Designer/Reviewer Checklist, References, and Credits and Acknowledgments will follow the summary sheet.

Credits and Acknowledgments

This introductory segment and the fact sheets that follow have been developed by Christopher B. Burke Engineering, LLC, and are primarily based upon similar segments contained in "Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers" published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this introductory segment and the fact sheets that follow. The valuable contribution of SEMCOG through sharing of this material for use in this introductory segment and the fact sheets that follow are hereby acknowledged.

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BMP Fact Sheet

CLUSTER-TYPE DEVELOPMENT

Cluster-type development (also known as open space development) concentrates development on smaller lots on a portion of a larger site. Clustering allows the site planner to avoid resource sensitive and constrained areas at a site, such as steep slopes and water-sensitive areas including riparian buffers, wetlands, and floodplains without sacrificing the level of development. Clustering reduces the amount of required infrastructure and various development-related costs. Clustering lends itself to residential development, with greatest potential in municipalities where large-lot residential development is typical. Clustering can reduce total impervious area and total disturbed areas at development sites, thereby reducing stormwater peak rates of runoff, reducing total volume of runoff, and reducing nonpoint source pollutant loads.

Figure 1 Pinehills Development, Plymouth, MA (MA Office of Energy and Environmental Affairs)

Potential Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes*	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Limited	Stormwater Quality Functions	
Retrofit	No	TSS	High
Highway/Road	No	TP	High
Recreational	Limited	NO_3	High
		Temperature	High

**Depending upon site size, constraints, and other factors.*

Additional Considerations	
Cost	Low
Maintenance	Low/Med
Winter Performance	High

Variations

- Clustering as an option
- Clustering mandated by the municipality
- Clustering with incentives such as density bonuses

Key Design Features

- Develop inventory
- Map sensitive areas
- Reduce total site disturbance and develop cluster plan
- Increase undisturbed open space

Benefits

- Reduces required infrastructure
- Increases open space
- Protects environmentally sensitive natural resources

Limitations

- Site specific based on land topography and individual conditions

Description and Function

Cluster-type development is driven by reducing minimum lot size, though not necessarily changing the total number of lots or amount of development occurring. As lot sizes decrease, the portion of the site which remains as undisturbed open space increases. If clustering is done carefully, this remaining open space can and should include those areas which are most sensitive environmentally and/or which offer special value functions not otherwise protected from development (e.g., high-quality woodlands areas).

Variations

One variation to a typical cluster-type development allows for a density bonus to incentivize use of this technique. A density bonus allows for additional lots to be added to the site beyond what the yield plan would show with a conventional subdivision. Proponents of this method state that allowing an additional lot or two may be the incentive needed to increase implementation of this technique. Opponents of this variation state that a density bonus is not needed since the development already costs less due to less stormwater and transportation infrastructure.

A second clustering variation for municipalities to consider, subject to legal review, is establishing clustering as the baseline requirement, at least in some zoning categories. Conventional non-clustered development would still be an option (variance, conditional use, etc.), but only if a variety of performance standards are satisfied.

A third variation for consideration relates to the nature and extent of development types subject to clustering provisions. As discussed above, single-family residential development at lower densities/on larger lots is ready-made for clustering. However, clustering concepts can provide LID benefits in larger corporate office parks, in retail centers, and other uses. Often this clustering concept takes on its own nomenclature e.g., New Urbanist, Smart Growth, Planned Integrated Development, and others. In these cases, not only are individual lots reduced in size, but the physical form of the development typically undergoes change (i.e., 50,000 square feet of retail can move from a one-story box to stacked development with a much different New Urbanist configuration). Depending upon the nature and extent of the uses involved, "clustering" of nonresidential uses (e.g., daytime offices with evening/ weekend retail), if carefully planned can offer potential for reduced parking requirements.

Applications

Residential Clustering

The most common clustering option is residential clustering on new development. **Figure 2** illustrates a more traditional development scenario where lots are placed across the entire site. In this example, the lot and house placement does avoid major natural features such as floodplain and wetlands, but still substantially encroaches into woodlands and riparian buffer features. Such a development layout ("yield plan") provides an estimate of a site's capacity to accommodate lots and houses at the base density hypothetically allowed under a local zoning ordinance.

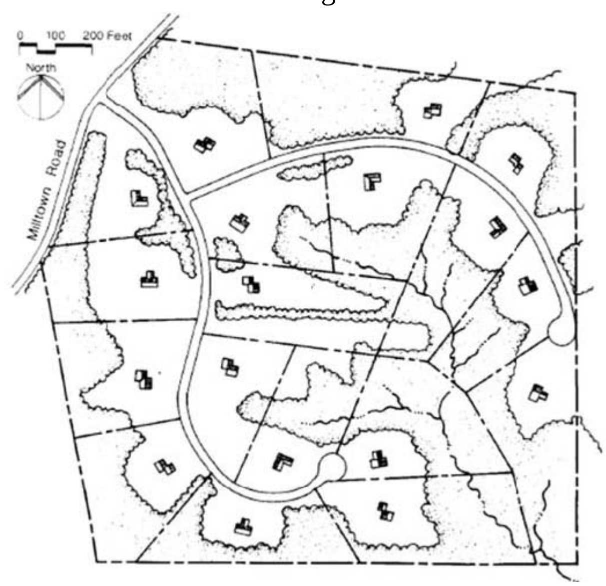

Figure 2 Conventional Development
Source: Growing Greener: Putting Conservation into Local Codes Natural Lands Trust, Inc., 1997

Figure 3 illustrates a "density-neutral" approach to clustering, where the number of lots and houses is held constant at 18 lots; however, the lot size has been reduced significantly allowing for 50 percent of open space area.

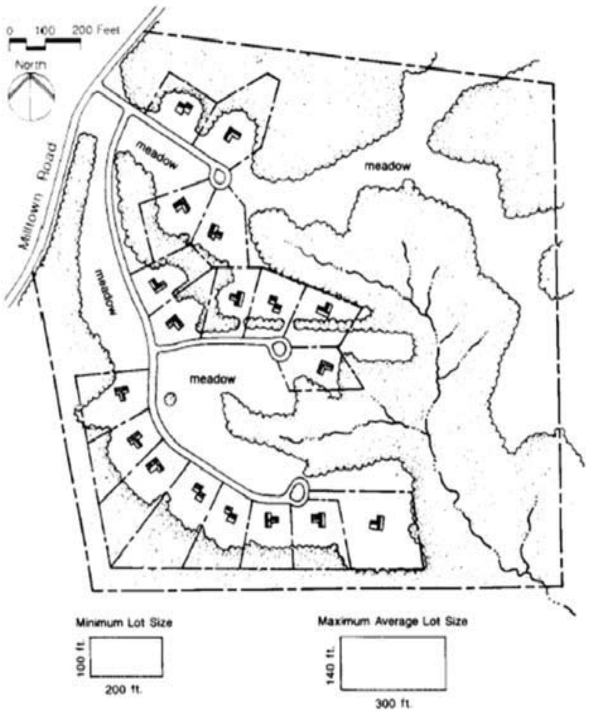

Figure 3 Clustered Development
Source: Growing Greener: Putting Conservation into Local Codes. Natural Lands Trust, Inc., 1997

Nonresidential Clustering

Conventional nonresidential development (e.g., retail commercial development) can also be configured in the form of low-rise (one story), relatively low-density strip or "big box" centers.

Design Considerations

The design process for implementing clustering at a proposed development site can occur in a variety of ways. Randall Arendt's *Growing Greener: Putting Conservation into Local Codes* (1997) provides clustering guidance in several straightforward steps. The process typically begins with the applicant applying existing conventional code to the site with any necessary net outs to develop a "yield plan." The purpose is to determine how many units can be developed conventionally:

- Step 1: Identify land to be protected: Primary conservation areas,
  - Identify land to be protected: Secondary conservation areas, and
  - Delineate potential development area.
- Step 2: Locate house sites on potential development area
- Step 3: Connect with streets and trails
- Step 4: Draw in lot lines

A major issue to address is the extent to which a clustering process is consistent with local ordinance requirements. How many house sites, and with what lot size, are going to be located in the potential development area?

If the existing local code is fully flexible, applicants can comprehensively "zone out" primary and secondary conservation areas and be confident that the baseline "yield plan" unit count can be loaded into the potential development area at whatever lot size is necessary (some applicants/developers believe that smaller lots translate into less valuable and marketable units and are reluctant to make considerable reductions in lot sizes). Often, however, such reduced lot sizes are less than the local ordinance allows. In such cases, the applicant is motivated to reduce primary and secondary conservation areas, so that the potential development area can be enlarged.

Stormwater Functions and Calculations

Volume and peak rate

Cluster-type development is a technique that results in increased open space, which reduces stormwater peak rate and volume. These open spaces are often associated with other BMPs from this manual, including preserving sensitive areas and protecting riparian corridors. These BMPs are not to be included in the disturbed stormwater management area when calculating runoff volume (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

Any portion of the open space that is mitigated or revegetated/reforested should be included in the disturbed stormwater management area, but may be granted runoff reduction recognition in accordance with the applicable BMP for native revegetation, soil restoration, minimize soil compaction, riparian buffer restoration, or minimize total disturbed area.

Water quality improvement

Clustering minimizes impervious areas and their associated pollutant loads, resulting in improved water quality. In addition, clustering preserves open space and other natural features, such as riparian corridors, which allow for increased infiltration of stormwater and removal of pollutant loads. (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

Maintenance

Preserving open space creates concerns regarding responsibility for maintenance activities. Legally, the designated open space may be conveyed to the municipality. More likely, ownership of these natural areas will be assumed by homeowners' associations or the specific individual property owners where these resources are located. Specific maintenance activities will depend on the type of vegetation present in the preserved natural area. For example, woodlands require little to no maintenance and open lawns require higher maintenance. An objective of cluster-type development is to conserve the existing natural systems with minimal, if any, intervention and disturbance.

Cost

Clustering is beneficial from a cost perspective. Costs to build 100 clustered single-family residential homes is less due to less land clearing and grading, less road and sidewalk construction (including curbing), less lighting and street landscaping, potentially less sewer and water line construction, potentially less stormwater collection system construction, and other economies of scale.

Post-construction, clustering also reduces costs. A variety of studies from Rutgers University's landmark *Costs of Sprawl* studies and later updates show that delivery of a variety of municipal services such as street maintenance, sewer and water services, and trash collection are more economical on a per person or per house basis when development is clustered. Furthermore, services such as police protection are made more efficient when residential development is clustered.

Additionally, clustering has been shown to positively affect land values. Analyses of market prices of conventional development over time in contrast with comparable clustered residential developments (where size, type, and quality of the house itself is held constant) indicate that clustered development increases in value at a more rapid rate than conventionally designed developments. This is partly due to the proximity to permanently protected open space.

Designer/Reviewer Checklist for Cluster-Type Development

ITEM	Page No.	YES	NO	N/A	NOTES
Has nonstructural BMP Protect Sensitive Resources been applied? If not, complete this BMP.	2, 3				
Has a baseline "yield plan" been developed by applicant?	2, 3				
What local ordinance provisions - obstacles and opportunities - exist for clustering?	3				
Has a Potential Development Area, or comparable, which avoids Sensitive Resources, been delineated?	3				
Has "yield plan" house/unit count been loaded into Potential Development Area?	3				
What clustered lot size assumptions are being used? Compatible with local ordinance?	3				
Compare disturbed area/developed area of "yield plan" with clustered plan?	3				

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BMP Fact Sheet

MINIMIZE SOIL COMPACTION

Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality caused by the land development process. Enhancing soil composition with soil amendments and mechanical restoration after it has been damaged is addressed in a separate structural BMP.

Figure 1 Areas where heavy equipment is not allowed are fenced off to avoid compaction of soils and damages to vegetation (MD Custom Homes, WI)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Med/High
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Limited	TSS	Med/High
Highway/Road	Limited	TP	Med/High
Recreational	Yes	NO_3	Low
		Temperature	Med/High

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	Low/Med

Key Design Features

- Reduce disturbance through design and construction practices
- Limit areas of heavy equipment
- Avoid extensive and unnecessary clearing and stockpiling of topsoil
- Use top quality topsoil; maintain topsoil quality during construction

Benefits

- Increases infiltration capacity
- Provides a healthy environment for vegetation
- Preserves low areas, which offer added benefit when runoff is directed there from impervious areas

Limitations

- Difficult to implement on small development sites

Description and Function

Minimizing soil compaction relates directly to reducing total site disturbance, site clearing, site earthwork, the need for soil restoration, and the size and extent of costly, engineered stormwater management systems. Ensuring soil quality can significantly reduce the cost of landscaping vegetation (higher survival rate, less replanting) and landscaping maintenance. Fencing off an area can help minimize unnecessary soil compaction.

Soil is a physical matrix of weathered rock particles and organic matter that supports a complex biological community. This matrix has developed over a long time period and varies greatly within the state. Healthy soils, which have not been compacted, perform numerous valuable stormwater functions, including:

- Effectively cycling nutrients,
- Minimizing runoff and erosion,
- Maximizing water-holding capacity,
- Reducing storm runoff surges,
- Absorbing and filtering excess nutrients, sediments, and pollutants to protect surface and groundwater,
- Providing a healthy root environment,
- Creating habitat for microbes, plants, and animals, and
- Reducing the resources needed to care for turf and landscape plantings.

Undisturbed soil consists of pores that have water-carrying and holding capacity. When soils are overly compacted, the soil pores are destroyed and permeability is drastically reduced. In fact, the runoff response of vegetated areas with highly compacted soils closely resembles that of impervious areas, especially during large storm events (Schueler, 2000). Recent research studies indicate that compacted soils from development practices end up as dense as concrete.

Applications

Minimizing soil compaction can be performed at any land development site during the design phase. It is especially suited for developments where significant "pervious" areas (i.e., post-development lawns and other maintained landscapes) are being proposed. If existing soils have already been excessively compacted, soil restoration is applicable (see Soil Restoration BMP Fact Sheet).

Design Considerations

Early in a project's design phase, the designer should develop a soil management plan based on soil types and existing level of disturbance (if any), how runoff will flow off existing and proposed impervious areas, trees and natural vegetation that can be preserved, and tests indicating soil depth and quality. The plan should clearly show the following:

1. **No disturbance areas**. Soil and vegetation disturbance is not allowed in designated no disturbance areas. Protecting healthy, natural soils is the most effective strategy for preserving soil functions. Not only can the functions be maintained, but protected soil organisms are also available to colonize neighboring disturbed areas after construction.

2. **Minimal disturbance areas**. Limited construction disturbance occurs, but soil restoration may be necessary for such areas to be considered fully pervious after development. In addition, areas to be vegetated after development should be designated minimal disturbance areas. These areas may allow some clearing, but no grading due to unavoidable cutting and/or filing. They should be immediately stabilized, revegetated, and avoided in terms of construction traffic and related activity. Minimal disturbance areas do not include construction traffic areas.

3. **Construction traffic areas**. Construction traffic is allowed in these areas. If these areas are to be considered fully pervious following development, a soil restoration program will be required.

4. **Topsoil stockpiling and storage areas**. If these areas are needed, they should be protected and maintained. They are subject to soil restoration (including compost and other amendments) following development.

5. **Topsoil quality and placement**. Soil tests are necessary to determine if it meets minimum parameters. Critical parameters include: adequate depth (four inches minimum for turf, more for other vegetation), organic content (five percent minimum), and reduced compaction (1,400 kPa maximum) (Hanks and Lewandowski, 2003). To allow water to pass from one layer to the other, topsoil must be "bonded" (See Construction Guidelines #4 below) to the subsoil when it is reapplied to disturbed areas.

Construction Guidelines

1. At the start of construction, no disturbance and minimal disturbance areas must be identified with signage and fenced as shown on the construction drawings.

2. No disturbance and minimal disturbance areas should be strictly enforced.

3. No disturbance and minimal disturbance areas should be protected from excessive sediment and stormwater loads while adjacent areas remain in a disturbed state.

4. Topsoil stockpiling and storage areas should be maintained and protected at all times. When topsoil is reapplied to disturbed areas it should be "bonded" with the subsoil. This can be done by spreading a thin layer of topsoil (2-3 inches), tilling it into the subsoil, and then applying the remaining topsoil. Topsoil should meet locally available specifications/ requirements.

Stormwater Functions and Calculations

Volume and peak rate reduction

Minimizing soil compaction can reduce the volume of runoff by maintaining soil functions related to stormwater infiltration and evapotranspiration. Designers that use this BMP can select a lower runoff curve number for calculating runoff volume and peak rate from the area of minimized soil compaction. See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards on how to calculate the runoff reduction recognition for this BMP.

Where no disturbance areas are specified, which are also sensitive areas maintained in their presettlement state, there will be no net increase in stormwater runoff from that area. Calculation methodology to account for the protection of sensitive areas is provided under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Water quality improvement

Minimizing soil compaction improves water quality through infiltration, filtration, chemical and biological processes in the soil, and a reduced need for fertilizers and pesticides after development. See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards for information on how to calculate the volume of runoff that needs water quality treatment.

Maintenance

Sites that have minimized soil compaction properly during the development process should require considerably less maintenance than sites that have not. Landscape vegetation, either retained or re-planted, will likely be healthier, have a higher survival rate, require less irrigation and fertilizer, and have better aesthetics.

Some maintenance activities, such as frequent lawn mowing, can cause considerable soil compaction after construction and should be avoided whenever possible. Planting low-maintenance native vegetation is the best way to avoid damage due to maintenance. No disturbance areas on private property should have an easement, deed restriction, or other legal measure imposed to prevent future disturbance or neglect.

Cost

Minimizing soil compaction generally results in significant construction cost savings. Design costs may increase slightly due to a more time intensive design.

Criteria to Receive Runoff Reduction Recognition for Minimize Soil Compaction BMP

To receive runoff reduction recognition under the local regulation, areas of no disturbance and minimal disturbance must meet the following criteria:

- ☐ No disturbance and minimal disturbance areas are protected by having the limits of disturbance and access clearly shown on the Stormwater Plan, all construction drawings, and delineated/flagged/fenced in the field.
- ☐ No disturbance and minimal disturbance areas are not be stripped of existing topsoil.
- ☐ No disturbance and minimal disturbance areas are not be stripped of existing vegetation.
- ☐ No disturbance and minimal disturbance areas are not be subject to excessive equipment movement. Vehicle movement, storage, or equipment/material lay-down is not be permitted in these areas.
- ☐ Use of soil amendments and additional topsoil is permitted in other areas being disturbed, as described above. Light grading may be done with tracked vehicles that prevent compaction.
- ☐ Lawn and turf grass are acceptable uses. Planted meadow is an encouraged use.
- ☐ Areas receiving runoff reduction recognition are located on the development project.

Designer/Reviewer Checklist for Minimize Soil Compaction References

ITEM	Page No.	YES	NO	N/A	NOTES
Have no disturbance areas been defined on plans (see minimize total disturbed area BMP)?	2				
Have no disturbance areas been fenced/flagged in field?	3, 4				
Have minimal disturbance areas been defined on plans?	2				
Have construction traffic areas been defined on plans?	2				
Is soil restoration BMP committed to construction traffic areas, post-construction phase?	2				
Are soil stockpiling and storage areas defined on plan?	3				
Have proper topsoil quality and placement specifications been committed in the plans?	3				

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BMP Fact Sheet

MINIMIZE TOTAL DISTURBED AREA

A key component of LID is to reduce the impacts during development activities such as site grading, removal of existing vegetation, and soil mantle disturbance. This can be achieved through developing a plan to contain disturbed areas.

Figure 1 Undisturbed areas are protected during construction (Lake County, OH Stormwater Management Department

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO_3	High
		Temperature	High

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	High

Key Design Features

- Identify and avoid special value and environmentally sensitive areas (See Protect Sensitive Areas BMP)
- Maximize undisturbed open space
- Minimize disturbance lot-by-lot
- Maximize soil restoration and restore soil permeability
- Minimize and control construction traffic areas
- Minimize and control construction stockpiling and storage areas

Benefits

- Reduced runoff volume
- Reduced peak rates
- High water quality benefits
- Increased infiltration capacity
- Provides healthy environment for vegetation

Limitations

- Difficult to achieve on small development sites

Description and Function

Disturbance at a development site can occur through normal construction practices, such as grading, cutting, or filling. Minimizing the total disturbed area of the site requires the consideration of multiple BMPs, such as cluster development and identifying and protecting sensitive areas. These BMPs serve to protect area resources by reducing site grading and maintenance required for long-term operation of the site.

Minimizing the total disturbed area of a site specifically focuses on how to minimize the grading and overall site disturbance, maximizing conservation of existing native plant communities and the existing soil mantle of a site. If invasive plant species are present in the existing vegetation, proper management of these areas may be required in order for the vegetation to achieve its greatest hydrological potential.

Minimize grading

Reduction in grading can be accomplished in several ways, including the conformation of the site design with existing topography and land surface, where road alignments strive to follow existing contours as much as possible, varying the grade and alignment criteria as necessary to comply with safety limits.

Minimize overall site disturbance

Site design criteria have evolved in local jurisdictions to ensure that developments meet safety standards (i.e. sight distance and winter icing) as well as certain quality or appearance standards. Roadway design criteria should be flexible in order to optimize the fit for a given parcel and achieve optimal roadway alignment. The avoidance of environmentally sensitive resources, such as important woodlands, may be facilitated through flexible roadway layout.

From the single lot perspective, the conventional lot layout can impose added earthwork and grading. Although the intent of these local requirements is to provide privacy and spacing between units, the end result is often a cleared and graded lot, which reduces stormwater benefits. And although configuring lots in a rectilinear shape may optimize the number of units, local jurisdictions should consider requiring that the total site be made to fit the natural landscape as much as possible.

Local criteria that impose road geometry are usually contained within the subdivision and land development ordinance. Densities, lot and yard setbacks, and minimum frontages are usually contained in the zoning ordinance. Flexibility in the following land development standards will help to minimize site disturbance on an individual lot basis, thereby achieving area-wide stormwater quality and quantity results:

- Road vertical alignment criteria (maximum grade or slope)
- Road horizontal alignment criteria (maximum curvature)
- Road frontage criteria (lot dimensions)
- Building setback criteria (yards dimensions)

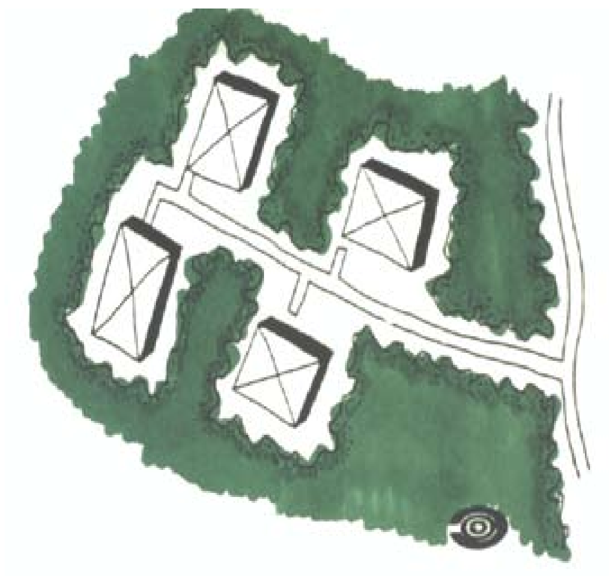

Figure 2 Minimally Disturbed Development
Source: Metropolitan Washington Council of Governments

Applications

Minimizing the total disturbed area of a site is best applied in lower density single-family developments, but can also be applied in residential developments of all types including commercial, office park, retail center, and institutional developments. Larger industrial park developments can also benefit from this BMP. However, as site size decreases and density and intensity of development increases, this BMP is uniformly more difficult to apply successfully. At some larger sites where Ultra Urban, Retrofit, or Highway/Road development is occurring, limited application may be feasible.

Design Considerations

During the initial conceptual design phase of a land development project, the applicant's design engineer should provide the following information, ideally through development of a Minimum Disturbance/Minimum Maintenance Plan:

1. **Identify and Avoid Special Value/Sensitive Areas**
   Delineate and avoid environmentally sensitive resources using existing data from appropriate agencies, as applicable.

2. **Minimize Disturbance at Site** Modify road alignments (grades, curvatures, etc.), lots, and building locations to minimize grading, and earthwork as necessary to maintain safety standards and local code requirements. Minimal disturbance design should allow the layout to best fit the land form without significant earthwork, such as locating development in areas of the site that has been previously cleared, if possible. If cut/fill is required, the use of retaining walls is preferable to earthwork. Limits of grading and disturbance should be designated on plan documentation submitted to the local jurisdiction for review/approval and should be physically designated at the site during construction via flagging, fencing, etc.

   In addition, utilizing natural drainage features generally results in less disturbance and requires less revegetation.

3. **Minimize Disturbance at Lot**
   To decrease disturbance, grading should be limited to roadways and building footprints. Local jurisdictions should establish maximum setbacks from structures, drives, and walks. These setbacks should be designed to be rigorous but reasonable in terms of current feasible site construction practices. These standards may need to vary with the type of development being proposed and the context of that development (the required disturbance zone around a low density single-family home can be expected to be less than the disturbance necessary for a large commercial structure), given necessity for use of different types of construction equipment and the realities of different site conditions. For example, the U.S. Green Building Council's Leadership in Energy & Environmental Design Reference Guide (Version 2.0 June 2001) specifies:

> "…limit site disturbance including earthwork and clearing of vegetation to 40 feet beyond the building perimeter, 5 feet beyond the primary roadway curbs, walkways, and main utility branch trenches, and 25 feet beyond pervious paving areas that require additional staging areas in order to limit compaction in the paved area… "

Stormwater Functions and Calculations

Volume

Any portion of a site that can be maintained in its predevelopment state by using this BMP will not contribute increased stormwater runoff and will reduce the amount of treatment necessary for Channel Protection Volume and Water Quality Volume requirements. In addition, isolated trees within disturbed areas that are protected in accordance to this BMP or the "Protect Sensitive Areas" BMP requirements can get "runoff reduction recognition" by receiving a curve number reflecting a woodlot in "good" condition for the pre-developed underlying soil conditions. Calculation methodology to account for this BMP is provided in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Peak rate

Runoff from the minimized disturbed area may be excluded from peak rate calculations for rate control, provided that the runoff from the area is not conveyed to and/or through stormwater management control structures. If necessary, runoff from the minimized disturbed area should be directed around BMPs and stormwater pipes and inlets by means of vegetated swales or low berms that direct flow to natural drainageways.

Water quality improvement

Water quality is benefited substantially by minimizing the disturbed area.

Maintenance

Minimizing site disturbance will result in a reduction of required maintenance of a site in both the short and long terms. Areas of the site left as intact native plant communities do not typically require replacement with hard surfaces or additional vegetation to retain function. On the other hand, artificial surfaces such as pavement or turf grass require varying levels of maintenance throughout the life of a development. Higher levels of disturbance will also typically require significant maintenance of erosion control measures during the active development of a parcel, thus adding to short-term development costs.

While intact natural areas may require small amounts of occasional maintenance to maintain function (typically through invasive species control), levels of maintenance required for hard surfaces or turf grass will remain static or, in most cases, increase over time. Avoiding disturbance to natural areas benefits the short-term developer and the long-term owner by minimizing time and money needed to maintain artificial surfaces.

Cost

The reduced costs of minimized grading and earthwork should benefit the developer. Cost issues include reduced grading and related earthwork as well as costs involved with site preparation, fine grading, and seeding.

Calculation of reduced costs is difficult due to the extreme variation in site factors, (amount of grading, cutting/filling, and haul distances for required trucking,). Some relevant costs factors are as follows (as based on R.S. Means, Site Work & Landscape Cost Data, 2007):

Site Clearing

- Cut & chip light trees to diameter $3,475/acre
- Grub stumps and remove $1,600/acre
- Cut & chip light trees to 24-inch diameter $11,600/acre
- Grub stumps and remove $6,425/acre

Strip Topsoil and Stockpile

- Ranges from $0.52- $1.78/yd^3 because of Dozer horse power, and ranges from ideal to adverse conditions
- Assuming six inches of topsoil, 500-ft haul: $2.75-9.86/yd^3
- Assuming six inches of topsoil, 500-ft haul: $9,922 -16,746 / acre

Site Preparation, Fine Grading, Seeding

- Fine grading w/ seeding: $2.91 /yd^2
- Fine grading w/ seeding: $14,084 /acre

In sum, total costs usually range from $29,000 - $49,000 per acre and could substantially exceed that figure at more challenging sites.

Criteria to Receive Runoff Reduction Recognition for Minimizing Total Disturbed Area

To receive runoff reduction recognition for protection of existing trees under a local regulation, the following criteria must be met:

- ☐ Area has not been subject to grading or movement of existing soils.
- ☐ Existing native vegetation are in a healthy condition as determined through a plant inventory and may not be removed.
- ☐ Invasive vegetation may be removed.
- ☐ Pruning or other required maintenance of vegetation is permitted. Additional planting with native plants is permitted.
- ☐ Area is protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field.
- ☐ Area is located on the development project.

Designer/Reviewer Checklist for Minimizing Total Disturbed Area

ITEM	Page No.	YES	NO	N/A	NOTES
Do local jurisdiction requirements for open space and related resource protection exist? Applied here?	2				
Have related BMPs (Protect Sensitive Areas, Natural Flow Pathways, Riparian Buffers, Clustering) been applied?	2				
Has Potential Development Area been defined?	3				
Have infrastructure connections/constraints been analyzed?	2				
On site, have roads been aligned to fit topography, to parallel contours and minimize cut/fill? On areas previously cleared? With terracing? Compatible with natural flow pathways?	3				
On lots, have buildings been located to reduce disturbance?	3				
On lots, have maximum disturbance radii been established and applied?	2				
No disturbance areas shall be clearly delineated on construction plans and flagged/fenced in field	3				
Have no disturbance zones been assessed qual-itatively for invasive management needs?	2				

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BMP Fact Sheet

PROTECT NATURAL FLOW PATHWAYS

A main component of LID is to identify, protect, and use natural drainage features, such as swales, depressions, and watercourses to help protect water quality. Designers can use natural drainage features to reduce or eliminate the need for structural drainage systems.

Figure 1 Long swales utilized in areas of natural drainage pathways, Lenexa, KS (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	No	Peak Rate	Med/High
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Low/Med
Highway/Road	Yes	TP	Low/Med
Recreational	Yes	NO_3	Low
		Temperature	Low

Additional Considerations	
Cost	Low
Maintenance	Low/Med
Winter Performance	Low/Med

Variations

- Check dams to slow velocity
- Earthen berms for additional storage
- Additional native vegetation for increased infiltration

Key Design Features

- Identifies and maps natural drainage features (e.g., swales, channels, ephemeral streams, depressions, etc.)
- Uses natural drainage features to guide site design
- Distributes non-erosive surface flow to natural drainage features
- Keeps non-erosive channel flow within drainage pathways
- Uses native vegetative buffers

Benefits

- Maximizes natural hydrological functions
- Reduces structural management practices
- Reduces management costs

Limitations

- Minimal water quality benefits

Description and Function

Many natural undeveloped sites have identifiable drainage features such as swales, depressions, and watercourses which effectively manage the stormwater that is generated on the site. By identifying, protecting, and using these features, a development can minimize its stormwater impacts. Instead of ignoring or replacing natural drainage features with engineered systems that rapidly convey runoff downstream, designers can use these features to reduce or eliminate the need for structural drainage systems.

Naturally vegetated drainage features tend to slow runoff and thereby reduce peak discharges, improve water quality through filtration, and allow some infiltration and evapotranspiration to occur. Protecting natural drainage features can provide for significant open space and wildlife habitat, improve site aesthetics and property values, and reduce the generation of stormwater runoff itself. If protected and used properly, natural drainage features generally require very little maintenance and can function effectively for many years.

Site designs should use and/or improve natural drainage pathways whenever possible to reduce or eliminate the need for stormwater pipe networks. This can reduce costs, maintenance burdens, and site disturbance related to pipe installation. Natural drainage pathways should be protected from significantly increased runoff volumes and rates due to development. The design should prevent the erosion and degradation of natural drainage pathways through the use of upstream volume and rate control BMPs, if necessary. Level spreaders, erosion control matting, revegetation, outlet stabilization, and check dams can also be used to protect natural drainage features.

Variations

Natural drainage features can also be made more effective through the design process. Examples include constructing slight earthen berms around natural depressions or other features to create additional storage, installing check dams within drainage pathways to slow runoff and promote infiltration, and planting additional native vegetation within swales and depressions.

Applications

As density and overall land disturbance decreases, this BMP can be used with a greater variety of land uses and development types. It is best used in residential development, particularly lower density single-family residential development. Where local jurisdiction ordinances already require a certain percentage of the undeveloped site to remain as undeveloped open space, this open space requirement can be overlain onto natural flow pathways/drainage features, as well as floodplains, wetlands, and related riparian areas. After minimizing runoff as much as possible, reduced runoff quantities can then be distributed into this natural flow pathway system, on a broadly distributed basis, lot by lot.

Other land uses such as commercial and industrial developments tend to be associated with higher density development. This results in higher

Figure 2 Schematic of a site design protecting natural drainage features.
Source: Georgia Stormwater Management Manual, Volume 2: Technical Handbook, First Edition. August, 2001

impervious coverage and maximum site disturbance allowances, making protecting and conserving natural flow pathways/drainage areas more difficult.

Applications for both retrofit and highway/road are limited. In terms of retrofitting, some developed sites may have elements of natural flow pathways/drainage features intact, although many presettlement site features may have been altered and/or eliminated. Developed sites of lower densities may offer limited retrofit potential. Similarly, highway/road projects are likely to be characterized by both limited site area, given the difficulties of right-of-way acquisition, as well as substantial disturbance of this limited site area.

Figure 3 Natural drainage features can guide the design Source: Delaware Department of Natural Resources and Environmental Control - Conservation Design for Stormwater Management

Design Considerations

1. **Identify natural drainage features**. Identifying and mapping natural drainage features is generally done as part of a comprehensive site analysis. This process is an integral first step of site design (**Figure 3**. Subtle site features such as swales, drainage pathways, and natural depressions should be delineated in addition to commonly mapped hydrologic elements such as wetlands, perennial and intermittent streams, and waterbodies.

2. **Use natural drainage features to guide site design.** Instead of imposing a two-dimensional paper design on a particular site, designers can use natural drainage features to steer the site layout. Drainage features define contiguous open space and other undisturbed areas as well as road alignment and building placement. The design should minimize disturbance to natural drainage features. Drainage features that are to be protected should be clearly shown on all construction plans. Methods for protection, such as signage and fencing, should also be noted on applicable plans.

3. **Use native vegetation**. Natural drainage pathways should be planted with native vegetative buffers and the features themselves should include native vegetation where applicable. If drainage features have been previously disturbed, they can be restored with native vegetation and buffers.

4. **County Regulated Drain Considerations**: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the County Surveyor's Office is highly recommended.

Stormwater Function and Calculations

Volume reduction

Protecting natural flow pathways can reduce the volume of runoff in several ways. Reducing disturbance and maintaining a natural cover reduces the volume of runoff through infiltration and evapotranspiration. Using natural flow pathways further reduces runoff volumes through allowing increased infiltration to occur, especially during smaller storm events. Encouraging infiltration in natural depressions also reduces stormwater volumes. Employing strategies that direct non-erosive sheet flow onto naturally vegetated areas also promotes infiltration – even in areas with relatively impermeable soils. (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.)

Peak rate mitigation

Protecting natural flow pathways can reduce the peak rate of runoff in several ways. Reducing disturbance and maintaining a natural cover reduces the runoff rate. Using natural flow pathways can lower discharge rates by slowing runoff and increasing onsite storage.

Water quality improvement

Protecting natural flow pathways improves water quality through filtration, infiltration, sedimentation, and thermal mitigation. (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.)

Maintenance

Natural drainage features that are properly protected and used as part of site development should require very little maintenance. However, periodic inspections are important. Inspections should assess erosion, bank stability, sediment/debris accumulation, and vegetative conditions, including the presence of invasive species. Problems should be corrected in a timely manner.

Protected drainage features on private property should have an easement, deed restriction, or other legal measure to prevent future disturbance or neglect.

Cost

Protecting natural flow pathways generally results in significant construction cost savings. Protecting these features results in less disturbance, clearing, and earthwork and requires less revegetation. Using natural flow pathways reduces the need and size of costly, engineered stormwater conveyance systems. Together, protecting and using natural flow pathways reduces and even eliminates the need for stormwater management facilities (structural BMPs), lowering costs even more.

Designer/Reviewer Checklist for Protect Natural Flow Pathways

ITEM	Page No.	YES	NO	N/A	NOTES
Identify in plan all natural flow pathways before proposed development?	2				
Identify in plan natural flow pathways protected post-development?	2				
Highlight in plan natural flow pathways which are integrated into stormwater management?	2, 3				
Have measures been taken to guarantee that natural pathways won't be negatively impacted by stormwater flows?	2				
Has runoff reduction recognition been calculated for natural flow pathways being protected?	3				

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BMP Fact Sheet

PROTECT RIPARIAN BUFFER AREAS

Riparian buffer areas are important elements of local communities' green infrastructure and/or LID tool box. These areas are critical to the biological, chemical, and physical integrity of our waterways. Riparian buffer areas protect water quality by cooling water, stabilizing banks, mitigating flow rates, and providing for pollution and sediment removal by filtering overland sheet runoff before it enters the water. The Environmental Protection Agency defines buffer areas as, "areas of planted or preserved vegetation between developed land and surface water, [which] are effective at reducing sediment and nutrient loads."

Physical restoration of riparian buffer areas is discussed in a separate structural BMP. A detailed description of the characteristics of riparian buffer areas is combined with a discussion of their stormwater functions in the Riparian Buffer Restoration BMP.

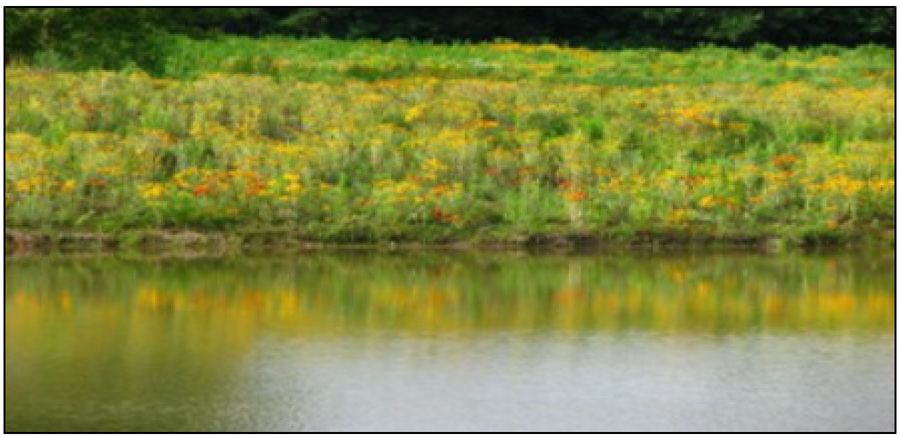

Figure 1 Urban riparian buffer (Hamilton County, IN Urban Conservation Association)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO_3	Medium
		Temperature	High

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	High

Key Design Features

- Physical protection
- Protection through planning tools

Benefits

- Improves water quality
- Reduces runoff velocities
- Reduces flow
- Enhances site aesthetics, habitat
- Reduces shoreline and bank erosion
- Improves flood control
- Reduces water temperature

Limitations

- Limited in reducing total runoff volumes
- Size of lot and/or development site may reduce ability to protect riparian buffers

Applications

As with the Protect Sensitive Areas nonstructural BMP, protecting riparian buffer areas has great value and utility for virtually all types of development proposals and land uses. This BMP works best on larger sites. Therefore, although riparian buffer programs should be advocated in the densest of settings, their application is likely to be limited in high density contexts. Creative design can maximize the potential of riparian buffers. Clustering and density bonuses are design methods available to increase the amount and connectedness of open space areas such as riparian buffers.

Design Considerations

Physical Design

Consider the following when protecting the proper riparian buffer area width and related specifications:

- Existing or potential value of the resource to be protected,
- Site, watershed, and buffer characteristics,
- Intensity of adjacent land use, and
- Specific water quality and/or habitat functions desired.

Riparian buffers can be divided into different zones (**Figure 2**) that include vegetation to enhance the quality of the body of water.

Zone 1: Also termed the "streamside zone," Zone 1 begins at the edge of the stream bank of the active channel and extends a minimum distance of 25 feet, measured horizontally on a line perpendicular to the water body. Undisturbed vegetated area aims to protect the physical and ecological integrity of the stream ecosystem. The vegetative target for the streamside zone is undisturbed native woody species with native plants forming canopy, understory, and duff layer. Where such forest does not grow naturally, the native vegetative cover appropriate for the area (such as grasses, forbs, or shrubs) is the vegetative target.

Zone 2: Also termed the "middle zone," Zone 2 extends immediately from the outer edge of Zone 1 for a minimum distance of 55 feet. This managed area of native vegetation protects key components of the stream ecosystem and provides distance between upland development and the streamside zone. The vegetative target for the middle zone is either undisturbed or managed native woody species or, in its absence, native vegetative cover of shrubs, grasses, or forbs. Undisturbed forest, as in Zone 1, is encouraged strongly to protect future water quality and the stream ecosystem.

Zone 3: Also termed the "outer zone," Zone 3 extends a minimum of 20 feet immediately from the outer edge of Zone 2. This zone prevents encroachment into the riparian buffer area, filters

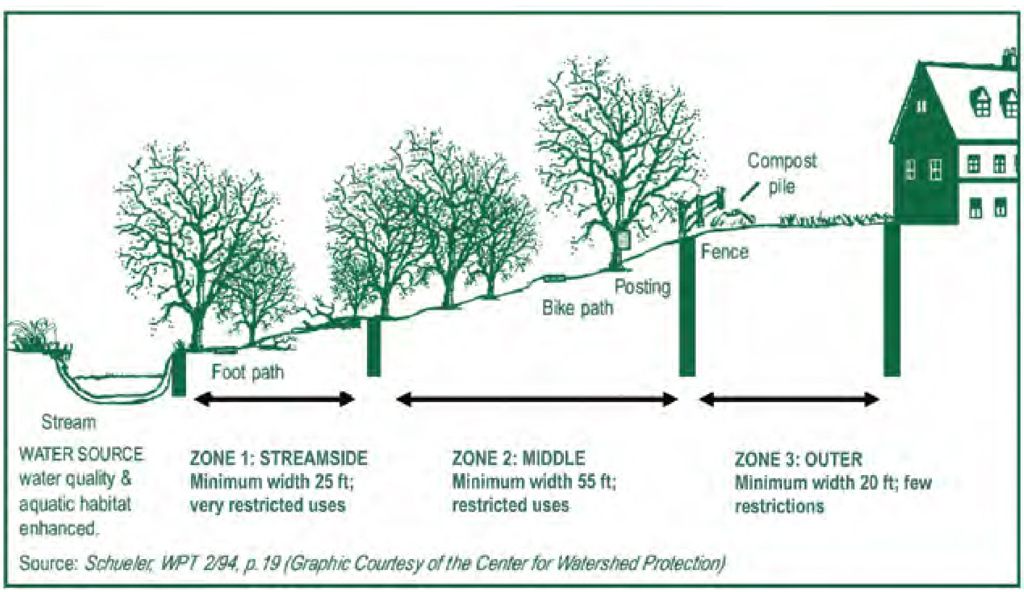

Figure 2 Buffer Width Recommendations
Source: Schueler, Watershed Protection Techniques, 1994

runoff from adjacent land, and encourages sheet flow of runoff into the buffer. The vegetative target for the outer zone is native woody and herbaceous vegetation to increase the total width of the buffer; native grasses and forbs are acceptable.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the County Surveyor's Office is highly recommended.

Local Planning and Riparian Buffers

Numerous tools exist at the community level to protect riparian buffers, including ordinances, integrating buffers into plans, and public education.

Local buffer regulations

To effectively manage riparian buffer areas, a community must properly plan for these resources. Some Indiana communities have riparian buffer ordinances that explicitly regulate these areas. Typical components of a riparian ordinance include:

- Exemptions,
- Width requirements,
- Permitted and prohibited uses within the riparian buffer,
- Maintenance requirements,
- Waivers and variances, and
- Maintenance and construction of utilities and public roads along the stream corridor.

Natural features setback standards establish a minimum setback (buffer width) from natural features to prevent physical harm or destruction of the feature. These standards recognize the relationship between terrestrial and aquatic ecosystems and should be applied to both lakes and rivers. Each community establishes buffer width standards at their discretion.

In general, the wider the buffer, the greater the number of ecological functions the riparian zone will provide. Communities may choose to establish fixed or variable width buffers or a combination of the two (Oakland County Planning & Economic Development Services).

Key planning elements of a local riparian protection program*

- Provide ample setbacks for sanitary facilities on buffer areas
- The wider the riparian buffer, the greater the water quality protection and habitat value of the area
- Establish setbacks from rivers and streams
- Regulate road placement adjacent to the riparian buffer area
- Restrict clearing, construction, and development within the 100-year floodplain
- Zone areas adjacent to riparian buffer areas for low intensity development
- Establish minimum lot size, frontage, and width requirements
- Include reference to floodplain, soil, and sedimentation controls administered by other agencies in riparian regulations
- Screen new structures with native vegetation
- Limit industrial use along riparian corridors and regulate through special use permits subject to pre-designated standards
- Limit the amount of impervious surfaces allowed adjacent to the buffer area
- Clearly outline appropriate and inappropriate uses of riparian buffer areas
- Promote intergovernmental coordination of regulations among communities along the river corridor

* - Adapted from *Michigan Wetlands – Yours to Protect*

Integrating buffer protection into plans

In addition to implementing a riparian buffer ordinance, communities can include riparian buffer area protection in the following planning tools:

- Local master plans,
- Park and recreation plans, and
- Subdivision and land development ordinances.

Park and recreation plans can adopt the goals, policies, and objectives for riparian protection that are listed in the community master plan, or include its own park and recreation-specific recommendations for riparian buffer management. Content may focus on defining appropriate and inappropriate recreational uses for riparian areas located within parks. Park and recreation plans may also provide guidelines for proper construction and maintenance of river access points, and rules and regulations for public access as these topics relate to potential impacts on riparian buffers (Oakland County Planning & Economic Development Services).

Riparian buffer education

Educational opportunities for the general public are an important component in community planning. Informing riparian owners of the importance of buffer areas will help to ensure these areas are understood and maintained over time. Public education activities include hosting public meetings, direct mailings to riparian homeowners, and educational workshops. These activities can be developed to meet the specific needs of your community through partnerships with local watershed groups.

Design Measures

The following elements represent a menu of design measures for riparian and natural resource protection that communities may choose to encourage or require developers to incorporate during the site plan review process.

Conservation subdivision or open space regulations:

- Prepare natural features inventory on proposed project sites.
- Require certain percentage of total parcel acreage to be retained as open space.
- Reference minimum buffer widths for riparian buffer areas and identify upland areas adjacent to riparian buffer areas as preferred green space designated for low-impact residential recreation activities.
- Advocate cluster development that concentrates construction on land with less conservation value, and allows owners of house lots in the development to share undivided ownership of the portion of property remaining in a scenic and natural condition.
- Advocate lot averaging standards for retaining riparian resources and natural features on smaller sites.

Lot size and density regulations:

- Provide flexible lot size and density standards to guide development away from a stream buffer or other sensitive land.
- Provide developers with density bonuses for land-conserving design and density disincentives to actively discourage land-consuming layouts.

Minimum frontage and road setback regulations:

- Provide flexibility in frontage and road setback standards to minimize development intrusion on riparian buffer areas.

Stormwater management guidelines:

- Regulate erosion control before, during, and after construction.
- Encourage developers to retain natural vegetation already protecting waterways.
- Create a variable-width, naturally vegetated buffer system along lakes and streams that also encompasses critical environmental

features such as the 100-year floodplain, steep slopes, and wetlands.
- Limit clearing and grading of forests and native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection.
- Promote riparian buffer areas as part of stormwater management planning.

Source: Planning for Green River Corridors, Oakland County Planning & Economic Development Services.

Stormwater Functions and Calculations

Any portion of a site that can be maintained in its presettlement state by using this BMP will not contribute increased stormwater runoff and will reduce the amount of treatment necessary. Calculation methodology to account for this BMP is provided in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Volume

Protected riparian buffers are not to be included in the disturbed stormwater management area when calculating runoff volume (See the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.)

Any portion of a riparian buffer area that is mitigated or revegetated/reforested should be included in the disturbed stormwater management area, but may be granted runoff reduction recognition in accordance with the applicable BMP for native revegetation, soil restoration, minimize soil compaction, riparian buffer restoration, or minimize total disturbed area.

Peak rate

Runoff from the riparian buffers may be excluded from peak rate calculations for rate control, provided that runoff from the riparian buffers is not conveyed to and/or through stormwater management control structures. If necessary, runoff from riparian buffers should be directed around BMPs and stormwater pipes and inlets by means of vegetated swales or low berms that direct flow to natural drainageways.

Water quality improvement

Water quality is benefited substantially by avoiding negative impacts which otherwise would have resulted from impacts to riparian buffers (e.g., loss of water quality functions from riparian buffers, from wetland reduction, etc.).

Cost

The costs of protecting riparian areas relate to a reduction in land available for development. However, most riparian areas are located in wetlands or floodplains, restricting the amount of buildable area.

Designer/Reviewer Checklist for Protect Riparian Buffer Areas

ITEM	Page No.	YES	NO	N/A	NOTES
Define municipal programs requirements or resources for riparian buffer protection, if any.	3-4				
Based on above and relevant sources, establish riparian buffer protection standards for development site.	3-4				
Map riparian resources at the site which need buffer protection.	3				
Apply Zone1/Zone2/Zone3 determinations; adjust for steep slopes and/or other natural/made factors.	2				
Overlay development program onto site, avoiding/minimizing Riparian Buffer Zone impacts.	3				
Contacted the County Surveyor's Office if the drainage pathway or stream is a County Regulated Drain?	3				
Provide for Riparian Buffer Zone maintenance?	4				
Provide for Riparian Buffer Zone protection in perpetuity (deed restrictions? covenants? easements?)?	--				

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PROTECT SENSITIVE AREAS

Protecting sensitive and special value features is the process of identifying and avoiding certain natural features during development. This allows these features to be used for various benefits, including reducing stormwater runoff.

Protecting sensitive areas can be implemented both at the site level and throughout the community. For prioritization purposes, natural resources and their functions may be weighted according to their functional value. Sensitive areas should be preserved in their natural state to the greatest extent possible and are not the appropriate place to locate stormwater infrastructure.

Figure 1 Tree Preservation during construction, Seattle, WA (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Yes	Stormwater Quality Functions	
Retrofit	No	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO_3	Low
		Temperature	High

Additional Considerations	
Cost	Low/Med
Maintenance	Low/Med
Winter Performance	High

Key Design Features

- Identify and map the following: floodplains, riparian areas, wetlands, woodlands, prairies, natural flow pathways, steep slopes, and other sensitive areas
- Identify and map potential development areas

Benefits

- Improved water quality
- Mitigation of runoff volume and peak rates

Limitations

- Difficult to implement on smaller sites

Description and Function

Protecting sensitive areas challenges the site planner to inventory and then, to the greatest extent possible, avoid resource sensitive areas at a site, including riparian buffers, wetlands, hydric soils, floodplains, steep slopes, woodlands, valuable habitat zones, and other sensitive resource areas. Development, directed away from sensitive areas, can be held constant, if BMPs such as cluster development are also applied.

A major objective of LID is to accommodate development with fewer impacts to the site. If development avoids encroachment upon, disturbance of, and impact to those natural resources which are especially sensitive to land development impacts and/or have special functional value, then low impact development can be achieved.

The first step in protecting sensitive areas is for the site planner to define, inventory, and map which resources are especially sensitive and/or have special value at a site proposed for development. Although many sensitive areas are common to all areas within Indiana, they can vary by region. The most detailed inventories are often compiled at the municipal or county level. For those areas without municipal or county-level data, state-level data can be used.

Preserving open space in multiple development areas throughout a community can ultimately evolve to form a unified open space system, integrating important conservation areas throughout the community and beyond. Many communities within Indiana are undertaking “green infrastructure” planning initiatives to proactively map these systems in order to restore or protect them as development occurs. The objective of these plans is to avoid impacting sensitive areas by: 1) carefully identifying and mapping these resources (resource areas, primary and secondary) from the start of the site planning process, and 2) striving to protect resource areas by defining other portions of the site free of these resources (potential development areas).

At the community level, local governments can implement community-wide regulations that protect sensitive areas such as wetlands, woodlands, riparian areas, and floodplains.

Potential Applications

Regardless of land use type, protecting sensitive areas is applicable across all types of land development projects, whether residential of varying densities or office park, retail center or industrial and institutional uses. As density and intensity of uses increases, ease of application of this BMP decreases. In such limited cases, it is especially important that sensitive areas be prioritized.

Design Considerations

1. **Identify, map, and inventory sensitive areas**. Mapping a site’s sensitive areas is an important step in preserving them. These features often include wetlands, steep slopes, woodlands, floodplains, and riparian areas. These data may give the community a general idea of the sensitive resources that could be on the site. In addition, the mapping will help the site designer define a potential development area which avoids encroachment upon and disturbance of defined and mapped sensitive areas.

   The inventory of sensitive areas should also include an assessment of the *quality* of the existing natural communities. Because plant communities will exist in a variety of states based on historic disturbance and degradation, the quality of the given community needs to be considered in comparison to other similar communities.

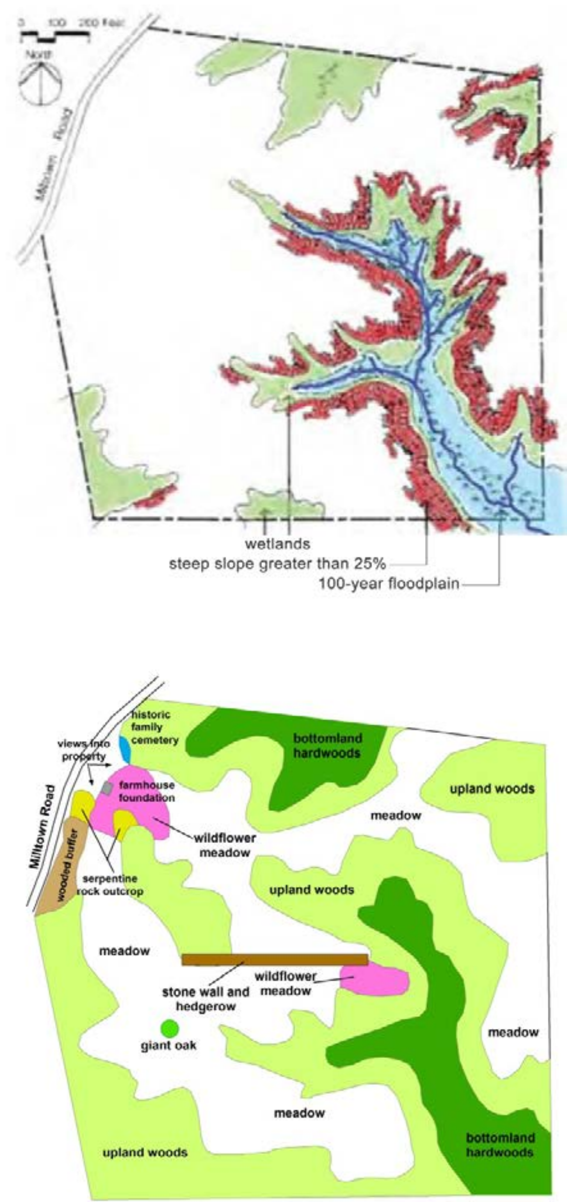

Figure 2 Map of Sensitive Areas (top) and Secondary Resources (bottom)
Source: Arendt, Randall. 1997

2. **Combine mapped natural features into a sensitive resource areas map, prioritizing areas to avoid development**. All sensitive resource mapping should be overlain to produce a sensitive areas map. In *Growing Greener*, Randall Arendt acknowledges prioritizing or weighting of sensitive areas by defining them as either Primary Conservation Areas (the most critical – avoid at all costs) or Secondary Conservation Areas (important resources which should be avoided when possible). Mapping the secondary resources of the site is an important step; the community can provide input to determine which features are important for preservation. Additionally, Primary and Secondary Conservation Areas can be defined in different ways, possibly varying with watershed context, (e.g., woodlands in some contexts may be classified as Primary Conservation Areas, rather than secondary).

3. **Map potential development areas; prioritize/ weight as necessary**. The potential development area should be delineated on the basis of protecting the primary and secondary resources on a site. Like the sensitive areas map, priorities and weightings may be reflected in the potential development area map. If sensitive areas have been prioritized, then weightings of potential development also may be established, varying with lack of degree of sensitivity measured by the resources themselves or overlapping of resources.

Figure 3 Map of Potential Development Areas
Source: Arendt, Randall. 1997

4. **Local regulation.** The level of regulation imposed on resource areas (primary and secondary) will likely vary by local jurisdiction. A local ordinance may prohibit and/or otherwise restrict development in primary and secondary resource areas, provided certain legal tests (such as a takings determination) are passed. Additional

activities include:

a. Conservation easement – Given to land conservancy or maintained by homeowners association.
b. Requirements in the master deed and bylaws for protection and preservation.
c. Boundary markers at edges of lots to minimize encroachment.
d. Cooperative agreements for stewardship of sensitive areas between homeowners' associations and local conservation organizations.

Stormwater Functions and Calculations

Any portion of a site that can be maintained in its predevelopment state by using this BMP will not contribute increased stormwater runoff and will reduce the amount of treatment necessary. Calculation methodology to account for this BMP is provided in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

Volume

Protected sensitive areas are not to be included in the disturbed stormwater management area when calculating runoff volume (see the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

Any portion of a sensitive area that is mitigated or revegetated/reforested should be included in the disturbed stormwater management area, but may be granted runoff reduction recognition in accordance with the applicable BMP for native revegetation, soil restoration, minimize soil compaction, riparian buffer restoration, or minimize total disturbed area.

Peak Rate

Runoff from the protected sensitive area may be excluded from peak rate calculations for rate control, provided that the runoff is not conveyed to and/or through stormwater management control structures. If necessary, runoff from protected sensitive areas should be directed around BMPs and stormwater pipes and inlets by means of vegetated swales or low berms that direct flow to natural drainageways.

Water Quality Improvement

Water quality is benefited substantially by avoiding negative impacts which otherwise would have resulted from impacts to sensitive areas (e.g., loss of water quality functions from riparian buffers, from wetland reduction, etc.)

Construction Guidelines

Although protecting sensitive areas happens early in the site plan process, it is equally important that the developer and builder protect these areas during construction.

The following guidelines describe good planning practices that will help ensure protection of a few common environmentally sensitive resources during construction.

Water Resources

- If vegetation needs to be reestablished, plant native species, or use hydroseed and mulch blankets immediately after site disturbance.
- Use bioengineering techniques, where possible, to stabilize stream banks.
- Block or protect storm drains in areas where construction debris, sediment, or runoff could pollute waterways.
- During and after construction activities, sweep the streets to reduce sediment from entering the storm drain system.
- Avoid hosing down construction equipment at the site unless the water is contained and does not get into the stormwater conveyance system.
- Implement spill control and clean-up practices for leaks and spills from fueling, oil, or use of hazardous materials. Use dry clean-up methods (e.g., absorbents) if possible. Never allow a spill to enter the stormwater conveyance system.
- Avoid mobile fueling of equipment. If mobile fueling is necessary, keep a spill kit on the fueling truck.

- Properly dispose of solid waste and trash to prevent it from ending up in our lakes and streams.
- When protecting riparian buffer areas, consider the three buffer zones in protection criteria:

Zone 1: Also termed the "streamside zone," Zone 1 begins at the edge of the stream bank of the active channel and extends a minimum distance of 25 feet, measured horizontally on a line perpendicular to the water body. Undisturbed vegetated area aims to protect the physical and ecological integrity of the stream ecosystem. The vegetative target for the streamside zone is undisturbed native woody species with native plants forming canopy, understory, and duff layer; where such forest does not grow naturally, then native vegetative cover appropriate for the area (such as grasses, forbs, or shrubs) is the vegetative target.

Zone 2: Also termed the "middle zone," Zone 2 extends immediately from the outer edge of Zone 1 for a minimum distance of 55 feet. This managed area of native vegetation protects key components of the stream ecosystem and provides distance between upland development and the streamside zone. The vegetative target for the middle zone is either undisturbed or managed native woody species or, in its absence, native vegetative cover of shrubs, grasses, or forbs. Undisturbed forest, as in Zone 1, is strongly encouraged to protect further water quality and the stream ecosystem.

Zone 3: Also termed the "outer zone," Zone 3 extends a minimum of 20 feet immediately from the outer edge of Zone 2. This zone prevents encroachment into the riparian buffer area, filters runoff from adjacent land, and encourages sheet flow of runoff into the buffer. The vegetative target for the outer zone is native woody and herbaceous vegetation to increase the total width of the buffer; native grasses and forbs are acceptable.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the County Surveyor's Office is highly recommended.

Wetlands

- Avoid impacts to wetlands whenever possible. If impractical, determine if a wetland permit is needed from the state or local government. (If any permit requirements or wetland regulations conflict with these guidelines, comply with the permit or regulation).
- Excavate only what is absolutely necessary to meet engineering requirements. Do not put excavated material in the wetland. (Excavated material could be used in other areas of the site to improve seeding success).
- If construction activities need to occur within a wetland, activities should be timed, whenever possible, when the ground is firm and dry. Avoid early spring and fish-spawning periods.
- Install flagging or fencing around wetlands to prevent encroachment.
- Travel in wetlands should be avoided. Access roads should avoid wetlands whenever possible. Crossing a wetland should be at a single location and at the edge of the wetland, if possible.
- Never allow a spill to enter area wetlands.

Floodplains

- Design the project to maintain natural drainage patterns and runoff rates if possible.
- Maintain as much riparian vegetation as possible. If riparian vegetation is damaged or removed during construction, replace with native species.
- Use bioengineering techniques to stabilize stream banks.
- Keep construction activity away from wildlife crossings and corridors.
- Stockpile materials outside of the floodplain and use erosion control techniques

Woodlands and Isolated Trees in Disturbed Areas

- Protect trees on sites with severe design limitations, such as steep slopes and highly erodible soils.
- Preserve trees along watercourses to prevent bank erosion, decreased stream temperatures, and to protect aquatic life.
- Protect the critical root zone of trees during construction. This is the area directly beneath a tree's entire canopy. For every inch of diameter of the trunk, protect 1.5 feet of area away from the trunk.

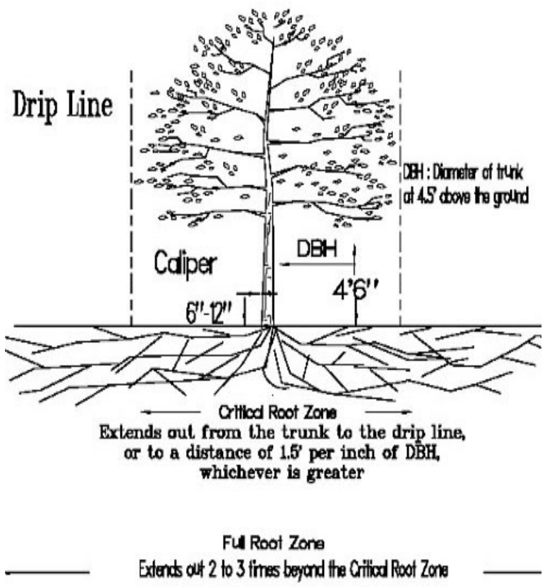

Figure 4 Critical Root Zone of a Tree
Source: www.ncufc.org/

- Avoid trenching utilities through the tree's critical root zone.
- Avoid piling excavated soil around any tree.
- Replace trees removed during construction with native trees.
- Conduct post-construction monitoring to ensure trees impacted by construction receive appropriate care.

General Construction Considerations

- Conduct a pre-construction meeting with local jurisdiction officials, contractors, and subcontractors to discuss natural resource protection. Communicate agreed-upon goals to everyone working on the project.
- Insert special requirements addressing sensitive natural areas into plans, specifications, and estimates provided to construction contractors. Note the kinds of activities that are not allowed in sensitive areas.
- Confine construction and staging areas to the smallest necessary and clearly mark area boundaries. Confine all construction activity and storage of materials to designated areas.
- Install construction flagging or fencing around sensitive areas to prevent encroachment.
- Excavate only what is absolutely necessary to meet engineering requirements. Do not put excavated material in sensitive areas. (Excavated material could be used in other areas of the site to improve seeding success.)
- Conduct onsite monitoring during construction to ensure sensitive areas are protected as planned. Conduct post-construction monitoring to ensure sensitive areas that were impacted by construction receive appropriate care.

Maintenance

The preservation of open space creates maintenance concerns related to who is required to perform the maintenance activities. Legally, the designated open space may be conveyed to the local government. More likely, ownership of these natural areas will be assumed by homeowners' associations or simply the specific individual property homeowners where these resources are located. Specific maintenance activities will depend upon the type of vegetation present in the preserved natural area where woodlands require little to no maintenance and open lawn require higher maintenance.

Figure 5 Protecting Woodlands

Cost

When development encroaches into sensitive areas, dealing with their special challenges invariably adds to development and construction costs. Sometimes these added costs are substantial, as in the case of working with wetlands or steep slopes.

Sometimes costs emerge only in longer-term operation, like encroachment in floodplains. This can translate into added risk of building damage for future owners, as well as health and safety impacts, insurance costs, and downstream flooding. If all short- and long-term costs of impacting sensitive areas were quantified and tallied, total real costs of sensitive area encroachment would increase substantially. Conversely, protecting sensitive areas results not only in cost savings, but also in water quality benefits.

At the same time, reduction in potential development areas resulting from protecting and conserving sensitive areas can have the effect of altering — even reducing — a proposed development program, thereby reducing development yield and profit. To address this, this BMP can be applied in tandem with the cluster development BMP.

Designer/Reviewer Checklist for Protect Sensitive Areas

ITEM	Page No.	YES	NO	N/A	NOTES
Define sensitive resources at proposed development site (see Key Design Features for list of sensitive resources)	1, 2				
Map sensitive resources at proposed development site	1, 2				
Prioritize/weight sensitive areas, as necessary and appropriate	3				
Develop potential development area map, or comparable, defined as converse/negative of sensitive areas, with priorities/weightings as necessary and appropriate.	3				
Determine baseline development plan, compatible with municipal ordinance.	2				
Iteratively fit baseline development plan to potential development area, minimizing sensitive area encroachment?	2				
Is this BMP process required by municipality? Yes or no, has applicant followed these steps, or comparable?	3, 4				

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BMP Fact Sheet

REDUCE IMPERVIOUS SURFACES

Reducing impervious surfaces includes minimizing areas such as streets, parking lots, and driveways. By reducing the amount of paved surfaces, stormwater runoff is decreased while infiltration and evapotranspiration opportunities are increased.

Figure 1 Grassed overflow parking areas (NEMO, University of Connecticut)

Applications		Stormwater Quantity Functions	
Residential	Yes	**Volume**	High
Commercial	Yes	**Groundwater Recharge**	High
Ultra Urban	Limited	**Peak Rate**	High
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Limited	**TSS**	Medium
Highway/Road	Yes	**TP**	Low
Recreational	Yes	**NO_3**	Low
		Temperature	Medium

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	High

Key Design Features

Streets

- Evaluate traffic volumes and street parking requirements
- Consult with local fire department and road agencies
- If available, consider a private road ordinance, as necessary, to minimize width
- Minimize pavement widths and lengths by using alternative roadway layouts, restricting on-street parking, minimizing cul-de-sac radii, and using permeable pavers

Parking Lots

- Evaluate parking requirements considering average demand as well as peak demand
- Consider smaller parking stalls and/or compact parking spaces
- Analyze parking lot layout to evaluate the applicability of narrowed traffic lanes and slanted parking stalls
- If appropriate, minimize impervious parking area by using overflow parking areas constructed of pervious paving materials

Lot Level

- Use maximum lot coverage requirements to manage the amount of impervious surfaces
- Reduce front yard setbacks to allow for shorter driveways
- Use alternative materials for patios, sidewalks, driveways, as appropriate

Benefits

- Directly reduces runoff volumes and peak rates
- Reduces development and maintenance costs
- Enhances aesthetics and habitat

Limitations

- Must comply with local private road ordinances
- Must comply with vehicular safety standards

Description and Function

Reducing street imperviousness performs valuable stormwater functions in contrast to conventional development in the following ways:

- Increases infiltration,
- Decreases runoff volumes,
- Increases stormwater time of concentration,
- Improves water quality by decreasing nonpoint source pollutant loading, and
- Decreases the concentration and energy of stormwater.

Jurisdiction	Residential Street Pavement Width	Maximum Daily Traffic (trips/day)
State of New Jersey	20 ft. (no parking)	0-3,500
	28 ft. (parking on one side)	0-3,500
State of Delaware	12 ft. (alley)	--
	21 ft. (parking on one side)	--
Howard County, Maryland	24 ft. (parking not regulated)	1,000
Charles County, Maryland	24 ft. (parking not regulated)	---
Morgantown, West Virginia	22 ft. (parking on one side)	--
Boulder, Colorado	20 ft.	150
	20 ft. (no parking)	350-1,000
	22 ft. (parking on one side)	350
	26 ft. (parking on both sides)	350
	26 ft. (parking on one side)	500-1,000
Bucks County, Pennsylvania	12 ft (alley)	--
	16-18 ft. (no parking)	200
	20-22 ft. (no parking)	200-1,000
	26 ft. (parking on one side)	200
	28 ft. (parking on one side)	200-1,000

Table 1 Narrow Residential Street Widths
Source: Cohen, 1992; Bucks County Planning Commission, 1980; Center for Watershed Protection, 1998

Imperviousness greatly influences stormwater runoff volume and quality by increasing the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources.

Stream degradation has been observed at impervious levels as low as 10-20 percent watershed-wide when these areas are managed conventionally. Recent findings indicate that degradation is observed even at much lower levels of imperviousness. Reducing imperviousness improves an area's hydrology, habitat structure, and water quality.

Design Considerations

Street Width

Streets usually are the largest single component of imperviousness in residential development. Universal application of high-volume, high-speed traffic design criteria results in excessively wide streets. Coupled with the perceived need to provide both on-street parking and emergency vehicle access, the end result is residential streets that may be 36 feet or greater in width.

The American Society of Civil Engineers (ASCE) and the American Association of State Highway and Transportation Officials (AASHTO) recommend that low-traffic-volume roads (less than 50 homes or 500 daily trips) be as narrow as 22 feet. Some municipalities have reduced their lowest trafficable residential roads to 18 feet or less. Higher-volume roads are recommended to be wider. **Table 1** provides sample road widths from different jurisdictions.

Need for adequate emergency vehicle access, notably fire trucks, also leads to wider streets. While it is perceived that very wide streets are required for fire trucks, some local fire codes permit roadway widths as narrow as 18 feet (**Table 2**). Concerns also exist relating to other vehicles and maintenance activities on narrow streets. School buses are typically nine feet wide, mirror to mirror.

Source	Residential Street Width
U.S. Fire Administration	18-20 ft.
Baltimore County, Maryland Fire Department	16 ft. (no on-street parking)
	24 ft. (on-street parking)
Virginia State Fire Marshall	18 ft. minimum
	24 ft. (no parking)
Prince George's County, Maryland Department of	30 ft. (parking on one side)
Environmental Resources	36 ft. (parking on both sides)
	20 ft. (fire truck access)
Portland, Oregon Office of Transportation	18 ft. (parking on one side)

Table 2 Fire Vehicle Street Requirements
Source: Adapted from Center for Watershed Protection, 1998

Prince George's and Montgomery Counties in Maryland require only a 12-foot driving lane for buses (Center for Watershed Protection, 1998).

Similarly, trash trucks require only a 10.5-foot driving lane. Trash trucks have a standard width of nine feet (Waste Management, 1997; BFI, 1997). In some cases, road width for emergency vehicles may be added through use of permeable pavers for roadway shoulders.

Snow removal on narrower streets is readily accomplished with narrow, eight-foot snowplows. Restricting parking to one side of the street allows accumulated snow to be piled on the other side of the street. Safety concerns are also cited as a justification for wider streets, but increased vehicle-pedestrian accidents on narrower streets are not supported by research. In fact, wider streets have been shown to promote increased speeds and accidents. The Federal Highway Administration states that narrower streets reduce vehicle travel speeds, lessening the incidence and severity of accidents.

Higher density developments require wider streets, but alternative layouts can minimize street widths. For example, in instances where on-street parking is desired, impervious pavement is used for the travel lanes, with permeable pavers placed on the road apron for the parking lanes. The width of permeable pavers is often the width of a standard parking lane (six to eight feet). This design approach minimizes impervious area while also providing an infiltration and recharge area for the impervious roadway stormwater.

Street Length

Numerous factors influence street length, including clustering techniques. As with street width, street length greatly impacts the overall imperviousness of a developed site. While no one prescriptive technique exists for reducing street length, alternative street layouts should be investigated for options to minimize impervious cover. Successful clustering design consistently has shown to reduce required street lengths, holding development programs constant (i.e., 100 homes successfully clustered on a 100-acre property results in a significant reduction in street length and total imperviousness than 100 homes conventionally gridded in large-lot development format).

Cul-de-sacs

The use of cul-de-sacs introduces large areas of imperviousness into residential developments. Some communities require the cul-de-sac radius to be as large as 50 to 60 feet. Simply reducing the radius from 40 feet to 30 feet can reduce the imperviousness by 50 percent (Schueler, 1995).

When cul-de-sacs are necessary, three primary alternatives can reduce their imperviousness; reduce the required radius, incorporate a landscaped island into the center of the cul-de-sac, or create a T-shaped (or hammerhead) turnaround (**Figure 2**). To reduce the radius, many jurisdictions have identified required turnaround radii (**Table 3**).

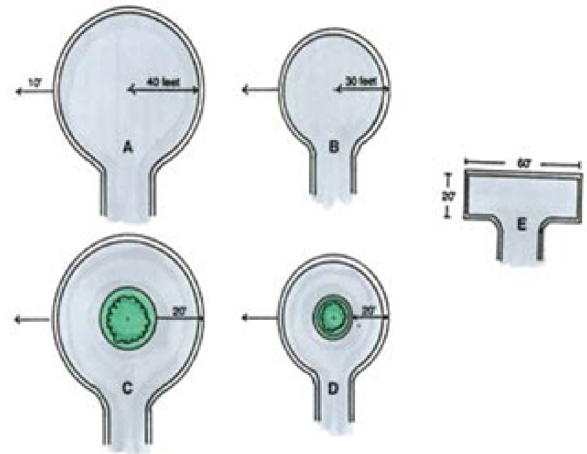

Figure 2 Five Cul-de-Sac Options
Source: Center for Watershed Protection, 1998

A landscaped island in the center of a cul-de-sac can provide the necessary turning radius, minimizing impervious cover. This island can be designed as a depression to accept stormwater runoff from the surrounding pavement, thus furthering infiltration. A flat apron curb will stabilize roadway pavement and allow for runoff to flow into the cul-de-sac's open center.

A T-shaped turnaround reduces impervious surface even further – yielding a paved area less than half that of a 30-foot radius turnaround. Since vehicles need to make a three-point turn to drive out, T-shaped turnarounds are most appropriate on streets with 10 or fewer homes.

Source	Radius
Portland, Oregon Office of Transportation	35 ft (with fire dept. approval)
Buck County, Pennsylvania Planning Commission	38 ft (outside turning radius)
Fairfax County, Virginia Fire and Rescue	45 ft
Baltimore County, Maryland Fire Department	35 ft (with fire dept. approval)
Montgomery County, Maryland Fire Department	45 ft
Prince George's County, Maryland Fire Department	43 ft

Table 3 Cul-de-sac Turning Radii
Source: Adapted from Center for Watershed Protection, 1998

Parking

Parking lots often comprise the largest percentage of impervious area. Parking lot size is dictated by lot layout, stall geometry, and parking ratios. Modifying any or all of these three aspects can serve to minimize the total impervious areas associated with parking lots. Parking ratio requirements and accommodating peak parking demand often provide parking capacity substantially in excess of average parking needs. This results in vast quantities of unused impervious surface. A design alternative to this scenario is to provide designated overflow parking areas.

The primary parking area, sized to meet average demand, might still be constructed on impervious pavement to meet local construction codes and American with Disabilities Act requirements. However, the overflow parking area, designed to accommodate increased parking requirements associated with peak demand, could be constructed on pervious materials (e.g., permeable pavers, grass pavers, gravel. See Porous Pavement BMP Fact Sheet). This design approach, focused on average parking demand, will still meet peak parking demand requirements while reducing impervious pavement.

Parking Ratios

Parking ratios express the specified parking requirements provided for a given land use. These specified ratios are often set as minimum requirements. Many developers seeking to ensure adequate parking provide parking in excess of the minimum parking ratios. Additionally, commercial parking is often provided to meet the highest hourly demand of a given site, which may only occur a few times per year. However, average parking demand is generally less than the typical required parking ratios (**Table 4**).

Parking spaces are comprised of five impervious components (Center for Watershed Protection, 1998):

1. The parking stall,
2. The overhang at the stall's edge,
3. A narrow curb or wheel stop,
4. The parking aisle that provides stall access, and

5. A share of the common impervious areas (e.g., fire lanes, traffic lanes).

Land Use	Parking Ratio	Average Parking Demand
Single Family Home	2 spaces per dwelling unit	1.1 spaces per dwelling unit
Shopping Center	5 spaces per 1,000 ft^2 of GFA	3.97 spaces per 1,000 ft^2 of GFA
Convenience Store	3.3 spaces per 1,000 ft^2 of GFA	Not available
Industrial	1 space per 1,000 ft^2 of GFA	1.48 spaces per 1,000 ft^2 of GFA
Medical/Dental Office	5.7 spaces per 1,000 ft^2 of GFA	4.11 spaces per 1,000 ft^2 of GFA

(GFA – Gross Floor Area, excluding storage and utility space)
Table 4 Example Minimum Parking Ratios
Source: Institute of Transportation Engineers, 1987; Smith, 1984: Wells, 1994

Of these, the parking space itself accounts for approximately 50 percent of the impervious area, with stall sizes ranging from 160 to 190 square feet.

Several measures can be taken to limit parking space size. First, jurisdictions can review standard parking stall sizes to determine their appropriateness. A typical stall dimension may be 10 feet by 18 feet, much larger than needed for many vehicles. The great majority of SUVs and vehicles are less than seven feet in width, providing opportunity for making stalls slightly narrower and shorter. In addition, a typical parking lot layout includes parking aisles that accommodate two-way traffic and perpendicularly oriented stalls. The use of one-way aisles and angled parking stalls can reduce impervious area.

Municipalities can also stipulate that parking lots designate a percentage of stalls as compact parking spaces. Smaller cars comprise a significant percentage of vehicles and compact parking stalls create 30 percent less impervious cover than average-sized stalls (Center for Watershed Protection, 1998).

Stormwater Functions and Calculations

Quantifying impervious areas at a proposed development site, pre- to post-development continues to dominate stormwater calculations. Stormwater calculations, as discussed in the discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards, are sensitive to pervious areas and their contribution to total volume of runoff, increased peak rate of runoff, and increased generation of nonpoint source pollutants. A reduction in imperviousness achieved through reduced street widths and lengths and reduced paved parking areas automatically reduces the volume and peak rate of runoff. To the extent that water quality is linked to runoff volume, reduction in imperviousness translates into a reduction in water quality management requirements as compared with standard design.

Maintenance

A reduction in impervious area results in decreased maintenance. For example, whether publicly or privately maintained, reducing roadway or parking lot imperviousness typically translates into reduction in all forms of maintenance required, from basic roadway repair to winter maintenance and snow removal.

Cost

Street Width

Costs for paving are estimated to be approximately $15 per square yard (Center for Watershed Protection, 1998), which would be considerably higher in current dollars. At this cost, for each one-foot reduction in street width, estimated savings are $1.67 per linear foot of paved street. For example, reducing the width of a 500-foot road by five feet would result in a savings of over $4,100, which would be considerably higher in current dollars. This cost is exclusive of other construction costs including grading and infrastructure.

Street Length

Factoring in pavement costs at $15 per square yard (as above), a 100-foot length reduction in a 25-foot-wide road would produce a savings in excess of $4,000 (much higher in current dollars).

In addition to pavement costs, costs for street lengths, including traditional curb and gutter and stormwater management controls, are approximately $150 per linear foot of road (Center for Watershed Protection, 1998), which would be considerably higher in current dollars. Decreasing road length by 100 feet would save an additional $15,000, for a combined total of $19,100.

Parking

Estimates for parking construction range from $1,200 to $1,500 per space (Center for Watershed Protection, 1998), which would be significantly higher in current dollars. For example, assuming a cost of $1,200 per parking space, reducing the required parking ratio for a modest 20,000 square foot shopping strip from five spaces per 1,000 square feet to four spaces per 1,000 square feet would represent a savings of $24,000.

Designer/Reviewer Checklist for Reducing Impervious Surfaces

ITEM	Page No.	YES	NO	N/A	NOTES
Check municipal ordinances for requirements/ specifications for roads, drives, parking, walkways, other (problems vs. opportunities?), including safety requirements.	1				
Have both macro (e.g., clustering) and micro site planning (e.g., reduced setbacks) activities been applied fully?	1, 3				
Have LID impervious reduction standards for roads, drives, parking, and other impervious areas been consulted and applied? ➢ *Street Width: See Tables 1 and 2 on Pages 2-3* ➢ *Cul-de-sac: See Table 3 on Page 4*	2-4				
Have roads and drives been reduced or narrowed as much as possible?	1-3				
Have macro parking ratios, lot layout, sharing strategies, and micro strategies (sizes/dimensions) been applied fully? ➢ *Parking Ratios: See Table 4 on Page 5*	4, 5				
Have pervious surfaces been applied for roads, drives, walks, parking, patios, and other hard surfaces, with maintenance been provided?	5				

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

STORMWATER DISCONNECTION

Minimize stormwater volume by disconnecting roof leaders, impervious roads, and driveways and direct runoff to other BMPs including vegetated areas that infiltrate at the site.

Figure 1 Curb cuts and vegetated areas along a Portland, OR street (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Limited	Peak Rate	High
Industrial	Limited	Stormwater Quality Functions	
Retrofit	Limited	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	NO_3	Low/Med
		Temperature	High

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	Low

Variations

- Rooftop disconnection
- Driveway/walkway/small parking areas/patio disconnection
- Minor roads
- Distribute to existing vegetated services
- Distribute to existing depressions, re-graded areas
- Distribute via curb cuts/curb removal

Key Design Features

- Encourages shallow sheet flow through vegetated areas
- Directs flows into stabilized vegetated areas, including on-lot swales and bioretention areas
- Limits the contributing rooftop area to a maximum of 500 ft^2 per downspout
- Maximizes overland flows
- Minimizes use of curb and gutter systems and piped drainage systems

Site Factors

- Water table to bedrock depth: two-foot minimum
- Soils: A, B
- Slope: maximum 5 percent
- Potential hotspots: No
- Max. drainage area: rooftop area of 1,000 ft^2

Benefits

- Reduces runoff volume and peak rate
- Increases water quality benefits

Limitations

- Requires area for infiltration

Description and Function

Roofs, roads, and driveways account for a large percentage of post-development imperviousness. These surfaces influence stormwater quality and runoff volume by facilitating the rapid transport of stormwater and collecting pollutants from rainfall, automobile leaks, and additional sources.

Disconnecting roof leaders and routing road and driveway runoff from conventional stormwater conveyance systems allows runoff to be collected and managed onsite. Runoff can be directed to designed vegetated areas for onsite storage, treatment, and volume control. This is a distributed, low-cost method for reducing runoff volume and improving stormwater quality through:

- Increasing infiltration and evapotranspiration,
- Decreasing stormwater runoff volume, and
- Increasing stormwater time of concentration.

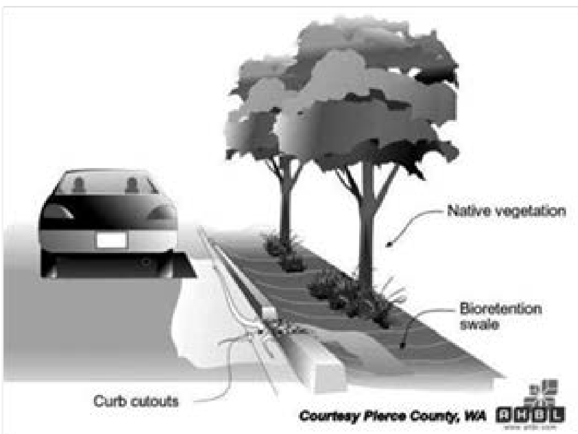

Figure 2 Curb cut-outs allow stormwater runoff from a parking lot to flow into a bioretention swale

The suitability of vegetated swales to receive runoff depends on land use, soil type, imperviousness of the contributing watershed, and dimensions and slope of the vegetated swale system. Use of natural low-lying areas is encouraged; natural drainage courses should be used and preserved.

Some ponding of water in areas receiving runoff may occur. It is important to take into account site usage when applying this BMP so that ponding does not unnecessarily interfere with expected site use (including backyard play areas). These areas should be shown on plan documents and protected with easements and deed restrictions.

Although this BMP can be applied in a variety of development settings, it will likely be more successful as lot size increases and density decreases. In situations where clustering has not been fully exercised and lots remain relatively large, these lots and the large areas of perviousness make perfect candidates for stormwater disconnection.

Variations

Disconnecting stormwater can be achieved through identifying the source of runoff and how it will be managed once disconnection occurs.

Source

Stormwater can flow from rooftop areas or from impervious areas such as driveways, walkways, small parking areas, minor roadways, and ancillary outdoor areas such as patios. (Note: Roads and highways, because of their greater runoff generation require Structural BMPs.)

Management practices

A common and successful management practice is to direct stormwater runoff to areas of existing vegetation. Vegetation can be of varying types, from established meadow to immature to mature woodland. A particular variation to consider is grading (crowning) of drives and minor roadways and

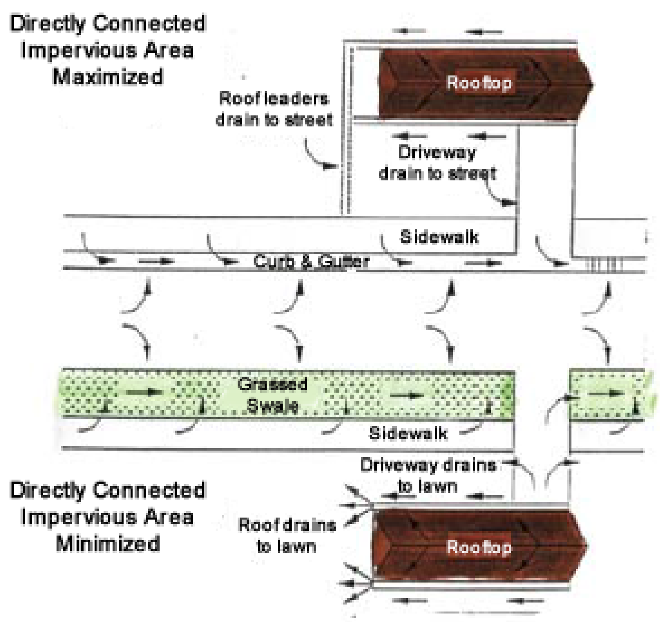

Figure 3 Difference between maximizing and minimizing runoff

eliminating curbing (or provision of curb cuts) so that runoff is allowed to flow in an even and non-concentrated manner onto adjacent vegetated areas.

In addition to directing runoff to vegetated areas, runoff may also be discharged to non-vegetated BMPs, such as dry wells, rain barrels, and cisterns for stormwater retention and volume reduction.

Another management practice includes routing runoff to existing grades and depressions that can be used to capture, store, and treat runoff. An important caveat is that applying this BMP should not prompt grading and disturbing areas which otherwise would not have been disturbed. However, assuming that grading and disturbance cannot be avoided, then subtle adjustments to grading may create additional management/storage opportunities for disconnected runoff.

An ideal coupling of BMPs is to minimize the total disturbed area of a site in coordination with stormwater disconnection. This not only reduces runoff volumes, peak rates, and pollutant loadings, but also provides multiple decentralized opportunities to receive disconnected flows.

Applications

Disconnection is ideal for most single-family developments, but can also be applied to many development sites, including larger office parks and retails centers. Industrial developments, with their larger impervious covers and greater runoff volumes, make stormwater disconnection a challenge. Even so, there are isolated applications which are beneficial and promote LID objectives. Similarly, Ultra Urban and Highway/Road developments with large flows would be more limited in application.

If downspout disconnection is applied as a retrofit, downspouts should be extended away from the basement as many footing drains are attached to the sanitary sewer system.

Design Considerations

Careful consideration should be given to the design of vegetated collection areas. Concerns pertaining to basement seepage and water-soaked yards are warranted, with the potential arising for saturated depressed areas and eroded water channels. Proper design and use of bioretention areas, infiltration

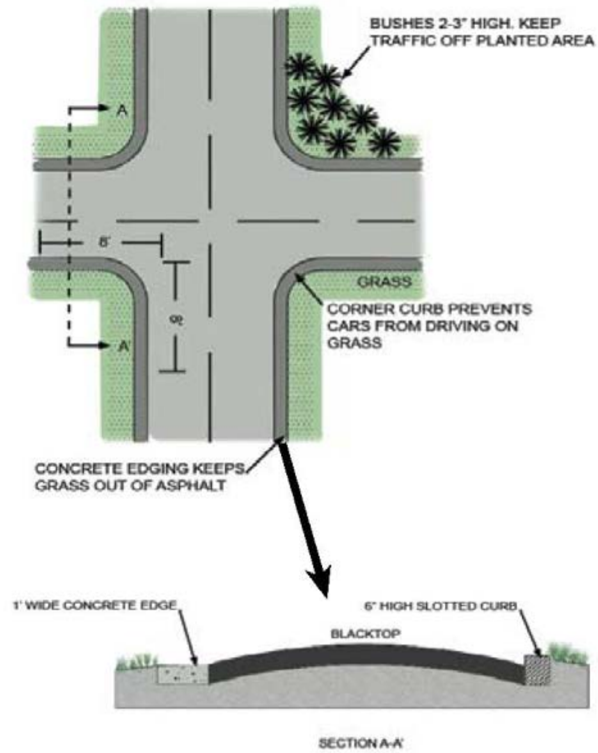

Figure 4   Curb cuts as a method of stormwater disconnection

trenches, and/or dry wells reduces or eliminates the potential for surface ponding and facilitates functioning during cold weather months. Where basements exist, consider the direction of groundwater flow and proximity.

Disconnection of small runoff flows can be accomplished in a variety of ways (Prince George's County Department of Environmental Protection, 1997; Maryland Department of the Environment, 1997; Cahill, 2008).

1. Encourage shallow sheet flow through vegetated areas.

2. Direct roof leader flow into BMPs designed specifically to receive and convey rooftop runoff.

3. Direct flows into stabilized vegetated areas, including on-lot swales and bioretention areas.

4. Rooftop runoff may also be directed to onsite depression storage areas.

5. The entire vegetated "disconnection" area should have a maximum slope of five percent.

6. Runoff should not be directed to vegetated areas if there is reason to believe that pollutant loadings will be elevated.

7. Roof downspouts or curb cuts should be at least 10 feet away from the nearest connected impervious surface to discourage "re-connections."

   a. Limit the contributing impervious area to a maximum of 1,000 sq. ft. per discharge point.

   b. Limit the contributing rooftop area to a maximum of 1,000 sq. ft. per downspout, where pervious area receiving runoff must be at least twice this size.

   c. For contributing areas greater than 1,000 sq. ft., leveling devices are recommended.

8. The maximum contributing impervious flow path length should be 75 feet.

9. For impervious areas, the length of the disconnection area must be at least the length of the contributing area (a minimum 75 feet for discharges which are concentrated; 25 feet for discharges which are not concentrated).

10. In all cases, flows from roof leaders should not contribute to basement seepage.

Stormwater runoff from disconnection needs to be monitored to ensure that flows do not become channel-ized that can result in erosion. Attention must be given to safe overflowing of larger storms, though clearly the more frequent smaller storms are of greatest interest and concern for successful design (use two-year storm for erosion analysis). Make sure flow of water and temporary ponding of water in management areas will not become a problem.

Stormwater Functions and Calculations

Peak rate and volume

This BMP reduces total volume and peak rates of runoff, as runoff is minimized from centralized stormwater management systems at the development site. Disconnection directly reduces volume and peak rates, which reduces the need for structural BMPs.

Water quality improvement

In terms of rooftop disconnection, this BMP has limited water quality benefit because rooftops typically have minimal pollution. In terms of other impervious area runoff sources being disconnected (driveways, walkways, ancillary areas, minor roads), water quality benefits can be significant given their greater pollutant loadings.

Maintenance

When disconnecting stormwater from rooftops or other impervious surfaces, maintaining the vegetated areas is required, but is limited.

If using structural BMPs, such as bioretention or vegetated swales, follow their specific maintenance activities. Typical maintenance of vegetation includes a biannual health evaluation of the vegetation and subsequent removal of any dead or diseased vegetation plus mulch replenishment, if included in the design. This can be incorporated into regular maintenance of the site landscaping. In some cases, if leaders are directing stormwater to lawn depressions, maintenance may be as simple as mowing.

Cost

Stormwater disconnection reduces both construction and maintenance costs due to less reliance on traditional stormwater management infrastructure. In addition, using existing or planned bioretention areas within a site creates a double usage of these BMPs.

Designer/Reviewer Checklist for Disconnection

ITEM	Page No.	YES	NO	N/A	NOTES
Are site factors conducive to disconnection (infiltration- related factors? slope? other?)	2, 3				
Is proposed development type (e.g., residential, commercial) conducive to disconnection? Free of hot spots?	3				
Have potential disconnection runoff sources been adequately reviewed/utilized in terms of proposed plan? ➢ *Max. slope for entire vegetated "disconnection" area:* ***5%*** ➢ *Minimum distance of roof downspouts or curb cuts from nearest connected impervious surface to discourage "re-connections":* ***10 feet*** ➢ *Max. contributing impervious area:* ***1000 ft^2 per discharge point*** ➢ *Max. contributing rooftop area (receiving pervious area must be twice this size):* ***1000 ft^2 per downspout*** ➢ *If contributing area > 1000 ft^2, leveling device is recommended* ➢ *Max. length of contributing impervious flow path:* ***75 feet*** ➢ *Minimum length of disconnection area to contributing impervious area:* ***75 feet for concentrated discharges; 25 feet for non-concentrated discharges***	3, 4				
Have potential disconnection management measures been used/exploited for all potential sources?	2, 3				
Have Criteria and Runoff Reduction Recognitions specifications for both rooftop and non-rooftop sources of disconnection been satisfied?	3				
Have disconnection calculation Runoff Reduction Recognitions been properly entered, as specified in Criteria and Runoff Reduction Recognitions?	3				

➢ *Denotes Minimum Design Consideration*

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Part 2

Structural BMPs for LID and Conventional Approaches

INTRODUCTION TO STRUCTURAL BEST MANAGEMENT PRACTICES FOR LID AND CONVENTIONAL APPROACHES

This introductory segment focuses on structural Best Management Practices (BMPs), and provides guidance on selecting the proper BMPs for a site. Specifically, this introductory segment discusses the following:

- The BMP selection process, including a matrix that compares the key applications and functions of each BMP,
- Cold climate considerations, and
- An overviews of format and contents of the structural BMP fact sheets

The structural BMPs, for which fact sheets are provided includes an array of practices that are used both for LID and conventional approaches to post-construction stormwater quality management.

BMP Selection Process

Selecting BMPs which accomplish as many stormwater functions as possible is important. At the same time, meeting a certain function or level of pollution control can require multiple BMPs integrated at the site, thus creating a "treatment train." Such treatment trains direct stormwater to or through multiple BMPs in order to achieve quantity and/or quality stormwater management objectives. In addition, implementing BMPs as part of a treatment train can also provide a level of backup and needed redundancy, which provides additional assurance if one BMP does not work as designed (e.g., maintenance problems, large storm event).

Some BMPs are more readily linked to other BMPs, better lending themselves to treatment train configurations. For example, water quality devices and constructed filters are often used in treatment trains to pre-treat runoff before entering different types of infiltration-driven BMPs. In addition, vegetated swales and vegetated filter strips link well with infiltration systems, rain gardens, wet ponds, and constructed wetlands in treatment trains.

How many of what BMPs should go where? Not all structural BMPs are appropriate for each land development at each site. The selection process of the large array of structural BMPs can be complex, as multiple factors are juggled. The successful design process requires balancing technical and nontechnical factors, and is summarized in **Figure 1**. In order to assist a quick comparison of the BMPs, **Table 1** provides summary information on potential applications, stormwater quality and quantity functions, cost, maintenance, and winter performance for each BMP.

Site design plan developers should look for performance data that cites total volume into the BMP and out of the BMP, with pollutant concentration or load information for each. One of the most useful databases for deriving performance information for structural stormwater facilities is the *International Stormwater BMP Database*, which includes information on more than 300 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance, and other study-related publications (www.bmpdatabase.org/). Information in the database aids in estimating the total pollutant load removed by a BMP; i.e., input load minus output load. The total load can be calculated using the volume of water entering into or discharged from the BMP over a given period, multiplied by the mean or average concentration of the pollutant. Another tool that summarizes BMP performance information is EPA's Urban BMP Performance Tool (www.bmpdatabase.org/). The post- construction stormwater quality management Chapter of the Technical Standards lists accepted, default levels of treatment rate for 4 major pollutants for pre-approved water quality control BMPs used in conventional or LID approaches.

The factors in Figure 1 help guide comprehensive stormwater planning and LID site design. Selecting BMPs requires balancing numerous factors, including the following:

Runoff quantity and runoff quality needs

BMP selection is often based on the pollutant loadings and amount of stormwater runoff. For example, in areas with high phosphorus runoff, infiltrations BMPs are excellent choices for removing phosphorus as long as other selection criteria (e.g., site factors) allow for these techniques. BMP fact sheets provide guidance relating to BMP performance in terms of runoff volume, groundwater recharge, peak rate, and water quality (total suspended solids, total phosphorous, nitrogen, and temperature).

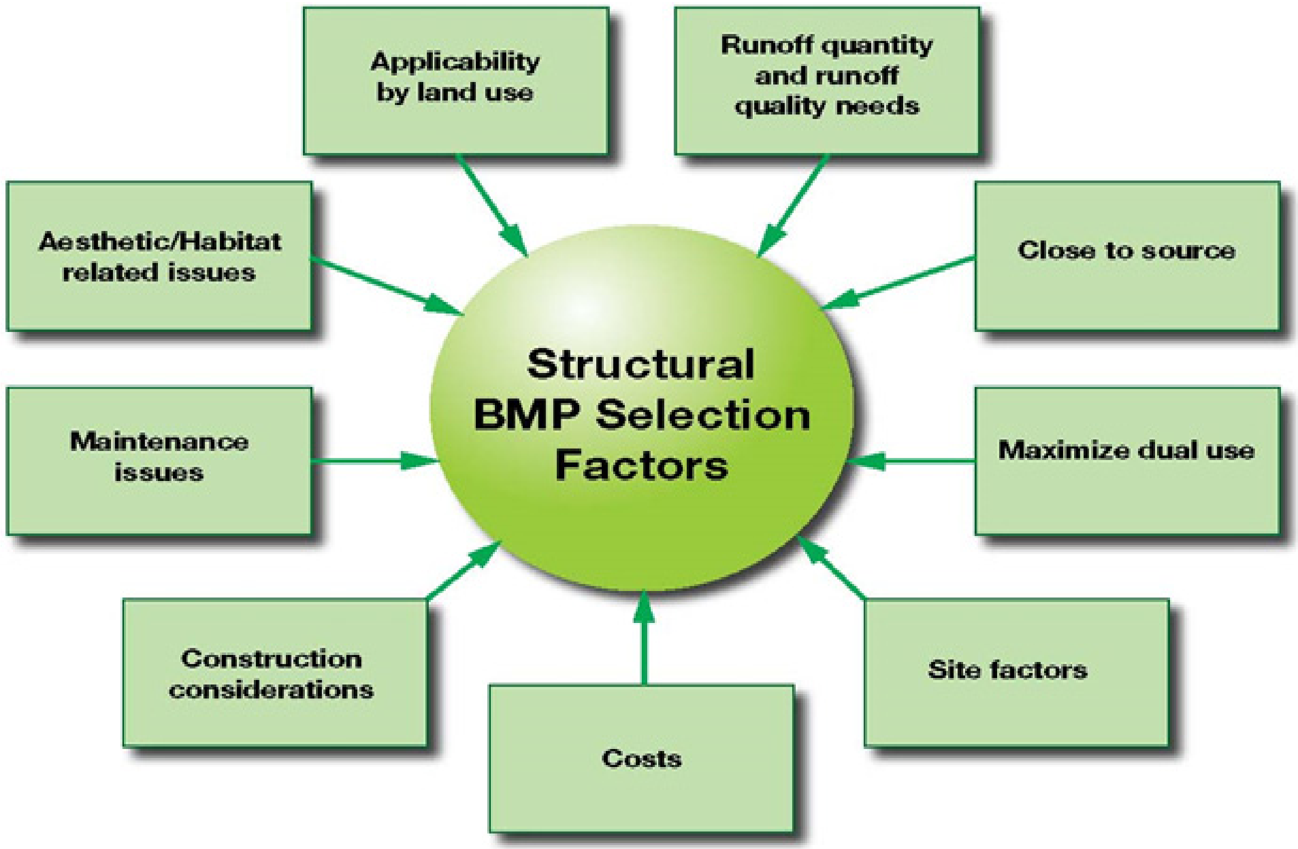

Figure 1 Factors to consider when selecting Structural BMPs

		Potential Applications							Stormwater Quantity Functions			Stormwater Quality Functions				Cost	Maintenance	Winter Perform.
		Residential	**Commercial**	**Ultra Urban**	**Industrial**	**Retro**	**Road**	**Rec**	**Volume**	**GW Recharge**	**Peak Rate**	**TSS**	**TP**	**NITROGEN[1]**	**Temp**			
Runoff Volume/ Infiltration	Bioretention	YES	YES	LIMITED	LIMITED	YES	YES	YES	MED/HIGH	MED/HIGH	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM
	Vegetated Filter Strip	YES	YES	LIMITED[2]	LIMITED	YES	YES	YES	LOW	LOW	LOW	MED/HIGH	MED/HIGH	MED/HIGH (NO_3)	MED/HIGH	LOW	LOW/MED	HIGH
	Vegetated Swale	YES	YES	LIMITED[2]	YES	LIMITED	YES	YES	LOW/MED	LOW/MED	LOW/MED	MED/HIGH	LOW/HIGH	MEDIUM	MEDIUM	LOW/MED\	LOW/MED	MEDIUM
	Pervious Pavement	YES[3]	YES	YES	YES[3]	YES[3]	LIMITED[3]	YES	HIGH	HIGH	MED/ HIGH	HIGH[4]	MED/HIGH	LOW	HIGH	MEDIUM	HIGH	MEDIUM
	Infiltration Basin	YES	YES	LIMITED[2]	YES	LIMITED	LIMITED	NO	HIGH	HIGH	HIGH	HIGH[4]	MED/HIGH	MED (NO_3)	HIGH	LOW/MED	LOW/MED	MED/HIGH
	Subsurface Infiltration Bed	YES	YES	YES	YES	YES	LIMITED	NO	HIGH	HIGH	HIGH	HIGH[4]	MED/HIGH	LOW	HIGH	HIGH	MEDIUM	HIGH
	Infiltration Trench	YES	YES	YES	YES	YES	YES	NO	MEDIUM	HIGH	LOW/MED	HIGH[4]	MED/HIGH	LOW/MED	HIGH	MEDIUM	LOW/MED	HIGH
	Dry Well	YES	YES	YES	LIMITED	YES	NO	NO	MEDIUM	HIGH	MEDIUM	HIGH[4]	MED/HIGH	LOW/MED	HIGH	MEDIUM	LOW/MED	HIGH
	Level Spreaders	YES	YES	NO	YES	YES	YES	YES	LOW	LOW	LOW	LOW	LOW	LOW (NO_3)	LOW	LOW	LOW	HIGH
	Berming	YES	YES	LIMITED[2]	YES	YES	YES	NO	LOW/MED	LOW/MED	MEDIUM	MED/HIGH	MEDIUM	MEDIUM	MEDIUM	LOW/MED	LOW/MED	MED/HIGH
	Planter Box	YES	YES	YES	LIMITED	YES	NO	LIMITED	LOW/MED	MED[5]	MEDIUM	MEDIUM	LOW/MED	LOW/MED	HIGH	MEDIUM	MEDIUM	MEDIUM
Runoff Volume/ Non-Infiltration	Vegetated Roof	LIMITED	YES	YES	YES	YES	N/A	YES	MED/ HIGH	LOW[6]	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM	MEDIUM
	Capture Reuse	YES	YES	YES	YES	YES	NO	YES	HIGH	LOW	LOW[3]	MED[4]	MEDIUM	MED (NO_3)	MEDIUM	Rain Barrel-LOW-Cistern-MED	MEDIUM	MEDIUM
Runoff Quality/ Non-infiltration	Constructed Wetland	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	HIGH	MEDIUM	MEDIUM	LOW/MED	HIGH	LOW/MED	MED/HIGH
	Wet Ponds/Retention Basin	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	HIGH	MEDIUM	MEDIUM	LOW/MED	HIGH	LOW/MED	MED/HIGH
	Constructed Filters	LIMITED	YES	YES	YES	YES	YES	YES	LOW[8]	LOW[8]	LOW[8]	HIGH[7]	MEDIUM[7]	MEDIUM[7]	LOW	MED/HIGH	HIGH	MEDIUM
	Water Quality Devices	YES	YES	YES	YES	YES	YES	YES	N/A	N/A	N/A	VARIES	VARIES	VARIES (NO_3)	NONE	VARIES	VARIES	HIGH
	Underground Detention	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	N/A	N/A	N/A	N/A	HIGH	MED/HIGH	MED/HIGH
	Extended Detention/ Dry Pond	YES	YES	YES	YES	YES	YES	YES	LOW	LOW	HIGH	MEDIUM	MEDIUM	LOW	LOW	HIGH	Sediment-LOW, Vegetation-High	MED/HIGH
Restoration	Riparian Buffer Restoration	YES	YES	YES	YES	YES	LIMITED	YES	LOW/MED	LOW/MED	LOW/MED	MED/HIGH	MED/HIGH	MED/HIGH (NO_3)	MED/HIGH	LOW/MED	LOW	HIGH
	Native Revegetation	YES	YES	LIMITED	YES	YES	LIMITED	YES	LOW/MED/ HIGH	LOW/MED/ HIGH	LOW/MED	HIGH	HIGH	MED/HIGH	MEDIUM	LOW/MED	LOW	MEDIUM
	Soil Restoration	YES	YES	YES	YES	LIMITED	YES	YES	MED	LOW	MEDIUM	HIGH	HIGH	MED/(NO_3)	MEDIUM	MEDIUM	LOW	HIGH

Table 1 BMP Summary Matrix

Notes:

1 – Reported as TN except as noted as (NO_3)
2 – Difficult to apply due to space limitations typically associated with these land uses.
3 – Applicable with special design considerations
4 – This assumes TSS loads and their debris have been managed properly before entering the BMP to prevent clogging
5 – Requires infiltration planter box.
6 – Although vegetated roofs can be used very successfully in combination with infiltration systems.
7 – Sand filters only (For filters with infiltration, see Subsurface Infiltration Bed section, or other infiltration BMP sections. For manufactured systems, see manufacturer's information, as well as results from independent verification.
8 – Increases with infiltration

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Close to source

Manage stormwater runoff as close to the source, or origin, as possible. Implementing this factor will vary by site and by the proposed development. For example, vegetated swales may work well in new development, but would unlikely be used as part of a retrofit.

Maximize dual use

Consider integrating stormwater management into already disturbed areas (e.g., stormwater recharge beds beneath parking areas, play fields on infiltration basins). This can minimize total disturbed area and, in some cases, provide recreational opportunities for residents or employees. For example, Blue Cross Blue Shield of Michigan located in Detroit, built a green roof on their parking structure that incorporated a running track for their employees.

Site factors

Each site should be inventoried for certain characteristics (e.g., soil type, depth to water table, slopes) which should be incorporated into the BMP selection process. For example, some sites in Indiana might be characterized by a high water table, surface bedrock, or extremely slow-draining soils, which would make using infiltration BMPs challenging. BMP fact sheets highlight these site factors which are discussed in more detail in each BMP Design Considerations section. In addition, each BMP has a Designer/Reviewer's Checklist that allows for quick review of the consideration of each key site factor in the design process.

Costs

BMP costs include both construction and long-term maintenance activities. Costs are often related to the size and nature of the development. The BMP fact sheets, as well as the more detailed discussions, provide approximate cost information, although construction and maintenance costs tend to be site and development-specific.

Construction considerations

Many BMPs have construction guidelines to provide additional guidance. For example, locating and properly using excavation equipment is critical during construction of infiltration BMPs to avoid soil compaction. In addition, recommended construction materials specific to individual BMPs are listed in the Recommended Materials Appendix.

Maintenance issues

Ease of maintenance and needed repairs are critical issues to consider in selecting a BMP. Some BMPs require greater maintenance to function properly. However, they may also achieve greater stormwater quantity and quality goals specific to the objectives of the site. Vegetated BMPs require various types of landscape care. Structural BMPs such as pervious pavement require periodic vacuuming, while infiltration basins, trenches, and dry wells are likely to require little maintenance. Some BMPs, especially those with plantings, may naturally improve in performance over time as vegetation grows and matures. In any case, general maintenance requirements are discussed for each BMP. The Maintenance Inspection Checklists Appendix includes example Inspection Checklists for maintenance activities that should be considered. In addition, the Stormwater Management Practices Maintenance Agreement Appendix includes Model Maintenance Agreements between property owners and the jurisdiction entity for maintenance of BMPs.

Aesthetic/Habitat related issues

Landscape enhancement is becoming an ever-greater goal in most communities and developments. In some cases, developers are willing to pay for BMPs which serve to make their developments more attractive and improve value and marketability. For example, rain gardens make yard areas more attractive. Wet ponds and constructed wetlands, naturally planted swales and filter strips, vegetated roofs, and many other BMPs can be integrated into landscape design while creating value and solving stormwater problems. In addition, many of these BMPs add habitat values and provide other environmental benefits. BMP fact sheets and the detailed BMP discussions provide additional information on aesthetics.

Applicability by land use

Some land uses lend themselves to certain BMPs. Low density residential development lacks large congregate parking areas conducive to pervious pavement with infiltration. Conversely, rain barrels are especially good for residential use, but vegetated roofs are unlikely to be used on single-family homes. Successful LID programs strive to match the BMP with the land use and user type, as listed on BMP fact sheets (applications) and detailed in each BMP discussion.

Cold Climate Considerations

Another important design consideration is how the BMP will function in our cold climate. The detailed design considerations in each BMP are written to address typical cold climate issues. In addition, cold climate is discussed throughout each BMP's various recommendations including a specific section dedicated to winter considerations.

In general, the techniques described in this manual can be used very effectively in cold climate settings such as Indiana (when the appropriate recommendations are followed). In addition, LID encourages stormwater management systems and treatment trains that can offer increased resiliency for cold climate issues.

Critical aspects of winter conditions are extremely cold temperatures, sustained cold periods, polluted snow-melt, and a short growing season (**Table 2**). Extreme cold can cause rapid freezing and burst pipes. Sustained cold can result in development of thick ice or snowpack all winter, as well as material it picks up as it flows over the land's surface.

Chloride is the cause of many problems associated with snowmelt runoff. Chloride is a very soluble chemical that migrates easily through treatment systems and soil. Avoiding over-application of chloride, and routing runoff properly are effective ways to reduce damage to LID BMPs.

General considerations

Avoid pipe freezing by laying pipes and installing underground systems below the typical frost line. Pipe freezing for standpipes is not likely to be an issue, but conveyance pipes laid nearly horizontal should be below the freezing line. In Indiana, most communities plant at least a foot or two of groundcover over stormwater pipes to minimize the risk of pipe freezing. Over-excavation and filling with sand and gravel around stormwater pipes will also help with frost penetration and frost heave.

Research in the Saginaw River valley in Michigan has shown (for the winter of 1996-1997) that soils in cultivated areas with little to no snow cover froze to depths of up to eight inches, while in areas with forest cover, leaf litter, and thin but persistent snow cover, frost depths only reached about an inch (Schaetzl and Tomczak, 2002). One conclusion that can be drawn from this is that plant material should be left in applicable stormwater BMPs to provide insulation through the winter. The ability of persistent snow cover

Climactic Condition	BMP Design Challenge
Cold Temperatures	• Pipe Freezing • Permanent pool ice cover • Reduced biological activity • Reduced oxygen levels during ice cover • Reduced settling velocities
Deep Frost Line	• Frost heaving • Reduced soil infiltration • Pipe freezing
Short Growing Season	• Short time period to establish vegetation • Different plant species appropriate to cold climates than moderate climates
Significant Snowfall	• High runoff volumes during snowmelt and rain-on snow • High pollutant loads during spring melt • Other impacts of road salt/deicers • Snow management may affect BMP storage

Table 2 Cold Climate Design Challenges

frozen soil layers in some BMPs. On the other hand, the deeper and more persistent the snow layer, the less severe the soil freezing. Water quality problems associated with snow melt occur because of the large volume of water released during rain and snow events. This runoff carries material that has accumulated in the to act as insulation also suggests that some BMPs such as bioretention areas, infiltration basins, and vegetated swales can be used for snow storage (as long as it does not cause physical damage to the vegetation or other BMP components). However, large amounts of sand or salt should be kept out of vegetated and infiltration BMPs. Sand and salt can smother and/ or kill plants and reduce infiltration/storage capacity. Sand should also never be used on or adjacent to porous pavement systems (see detailed BMP section).

In addition, some BMPs, such as bioretention areas should be installed with a mulch layer that is two to three inches thick. For maximum insulation effectiveness, the mulch should be spread evenly and consistently throughout the BMP (for details on mulch see the individual BMP sections).

All biological activity is mediated by temperature. Cold winter temperatures significantly decrease nutrient uptake and pollutant conversion processes by plants and microbes; however, soil microbes still live and consume nutrients even in the dead of winter. Accumulation of chloride is generally not a problem in shallow biological systems, as long as very highly concentrated levels are not directly routed to them.

Winter Pollution Prevention Tips

- Choose proper de-icing materials
- Consider pre-wetting brine treatments to salt for better application
- Load salt trucks on covered, impervious pads
- Calibrate salting vehicles often
- Properly manage salt storage piles
- Identify and avoid salt-sensitive areas prior to plowing or salting

Infiltration considerations

As water cools its viscosity increases, reducing particle-settling velocities and infiltration rates into the soil. The problem with infiltration in cold weather is theat ice that forms both over the tops of infiltration practices and in the soil pore spaces. To avoid these problems to the extent possible, the BMP must be actively managed to keep it dry before it freezes in the fall. This can be done by various methods including limiting inflow, under-drainage, and surface disking. Routing the first highly soluble portions of snowmelt to an infiltration BMP provides the opportunity for soil infiltration and treatment.

Infiltration practices are prohibited in proximity to public water supply wells as discussed in the Post-Construction Stormwater Quality Chapter, Section F, Step 5 of the Technical Standards.

Snow Storage Tip

Commercial and industrial areas that plow their parking and paved areas into big piles on top of pavement could greatly improve runoff management if instead, they dedicated a pervious area within their property for the snow. Even pushing the plowed snow up and over a curb onto a pervious grassed area will provide more treatment than allowing snow to melt on a paved surface and run into a storm sewer.

Detention considerations

For BMPs with a permanent pool, winter conditions can create ice layers and reduce biological activity, oxygen levels, and settling velocities. Ice layers can reduce the permanent pool volume, act as an impervious surface during rainfall, and potentially force incoming water under ice layers and scour bottom sediments. Ice layers can also reduce the oxygen exchange between the air-water interface. If low oxygen levels extend to the sediment-water interface, they can cause some adsorbed pollutants, such as phosphorus and some metals, to be released back into the water column. Reduced settling velocities will potentially result in lower pollutant removal rates.

Minimizing the effect of ice cover can help address these issues and can be accomplished by maintaining design storage volumes. Installing a control mechanism, such as a valve, weir, or stop-log, can reduce or eliminate outflow for the normal water quality volume. This volume is then made available for meltwater, which can be held and slowly released.

It is important to recognize the potential for detention facilities to incur a buildup of pollutants (mostly chloride applied to impervious surfaces) throughout the winter. A balance needs to be considered in deciding whether to adjust the detention level to pass pollutant-laden runoff downstream or retain as much as possible for later release when flows are higher. Retaining polluted water all winter long only to discharge it all at once in the spring is not in the best interest of receiving waters; however, this is what can happen in a detention BMP that is not being managed for seasonal conditions. In no case should detention BMPs be drained in the spring after a winter-long accumulation of under-ice contaminants. If lowering is done, it should occur in late fall prior to freeze-up.

Chloride-laden runoff can be denser than water already in a basin, so it often pools at the bottom of the basin. Without some level of mixing in the basin, the pool can increase in chloride concentration over time. This is especially important to consider during dewatering, or if the pond will be used for irrigation and a pump is placed in the bottom of the pond. Altering pump placement or testing the bottom water before pumping are two methods to avoid discharge or use of salty water.

Overview of the Format of the Structural BMP Fact Sheets

As with the nonstructural chapter, each BMP starts with a summary sheet. This summary sheet provides a quick overview of the BMP. Following each summary sheet is detailed information on the BMP which includes:

Variations

Discusses the variations to the BMP, if they are applicable. Examples include alternatives in design that can increase storage capacity or infiltration rates.

Applications

Indicates in what type of land use the BMP is applicable or feasible.

BMP Family	BMP	Considerations
Runoff Volume Minimization	Natural area conservation	Preserving pervious areas for meltwater to infiltrate is effective to control volume
	Soil amendments	Enhancing soil permeability will increase infiltration of meltwater
	Reducing impervious surface	Preserving pervious areas for meltwater to infiltrate is effective to control volume and minimize pollutants
	Grass drainage channel	Routing meltwater over a pervious surface will yield some reduction in flow and improved water quality
	Rain barrel/cistern	Capturing meltwater from a building will reduce volume but ice build-up could be a problem unless collection occurs below frost line
	Permeable pavement	Recent research has shown this approach to be successful in cold climates when properly installed and maintained, and when sanding is kept to a minimum
	Dry well	Effective as long as system is installed below the frost line to avoid ice build-up
	Planter box	These are designed more for the growing season, but they do provide a sump area for runoff to collect and will infiltrate some volume
	Vegetated roof	Recent research shows that slow melting in the spring reduces the volume running off of roof surfaces
Bioretention	Rain gardens	By definition, these are growing-season practices, but they do provide a sump area for storage and some infiltration during a melt
Filtration	Constructed filter	Surface systems need to be fully dry before freeze-up for these to work properly; subgrade systems can be very effective for meltwater treatment
	Vegetated filter	Vegetative filtering is reduced once vegetation dies back in fall; some physical filtering will occur if vegetation density and depth are sufficient
Infiltration	Trench	Effective when designed, installed, and maintained properly; caution applies to limitations on source area to avoid high concentrations of chloride and toxics
	Basin	See above comment
Detention Facilities	Forebay	Effective if designed with enough available volume to accommodate spring meltwater
	Storage components	Adaptations must be made to allow meltwater runoff to achieve appropriate amount of treatment; treatment effectiveness usually lower in warm weather
	Outlet	Proper design of the outlet structure can be the key to ponding effectiveness
Constructed Wetlands	Forebay	See comment for forebay above
	Storage components	Volume will be less than typical pond, but provide location for storage, some infiltration, filtration, and some microbial activity; biological activity at a minimum

Table 3 Additional BMP considerations for cold climate use

Design Considerations

This section includes a list of technical procedures to be considered when designing for the individual BMP. This specific design criteria is presented, which can assist planners in incorporating conventional or LID techniques into a site design, as well as provide a basis for reviewers to evaluate submitted conventional or LID techniques.

Stormwater Calculations

Provides specific guidance on achieving sizing criteria, volume reduction, and peak rate mitigation, as applicable. This section also references the Post-Construction Stormwater Quality Management Chapter of the Technical Standards which discusses in detail how to achieve a specific standard or implement measures that contribute to managing water onsite in a more qualitative manner.

Construction Guidelines

Provides a typical construction sequence for implementing the BMP. However, it does not specifically address soil erosion and sedimentation control procedures. Erosion and sediment control methods need to adhere to the the Post-Construction Stormwater Quality Management Chapter of the Technical Standards construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM's Soil Erosion and Sedimentation Control (Rule 5) Program.

Maintenance

Provides guidance on recommended maintenance procedures for the BMP.

Winter Considerations

Discusses how well the BMP performs in Indiana's cold climate.

Cost

Provides general cost information for comparison purposes. If specific dates of costs are not referenced in this section, the costs reflect 2007 conditions.

Designer/Reviewer's Checklist

Developed to assist a designer and or reviewer in evaluating the critical components of a BMP that is being designed. It references not only individual design considerations, but also suggests review of additional pertinent sections of the Technical Standards that may need to be considered for implementation of that BMP.

References

Provides a list of sources of information utilized in the creation of this section of the manual. This list also provides sources that can be used for additional information.

References

Schaetzl, R.J. and Tomczak, D.M. "Wintertime Temperatures in the Fine-Textured Soils of the Saginaw Valley, Michigan," *The Great Lakes Geographer*, v.8 (2), pp.87-99, 2001.

Minnesota Stormwater Manual, 2006. Minnesota Pollution Control Agency, St. Paul, MN.

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Credits and Acknowledgments

This introductory segment and the fact sheets that follow have been developed by Christopher B. Burke Engineering, LLC, and are primarily based upon similar segments contained in "Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers" published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this introductory segment and the fact sheets that follow. The valuable contribution of SEMCOG through sharing of this material for use in this introductory segment and the fact sheets that follow are hereby acknowledged.

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BMP Fact Sheet

BIORETENTION (RAIN GARDENS)

Bioretention areas (often called rain gardens) are shallow surface depressions planted with specially selected native vegetation to capture and treat stormwater runoff from rooftops, streets, and parking lots.

Figure 1 Residential rain garden, Lenexa KS (USEPA, picasaweb)

Stormwater Quantity Functions			
Residential	Yes	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Med/High
Ultra Urban	Limited	Peak Rate	Medium
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	High
Highway/Road	Yes	TP	Medium
Recreational	Yes	TN	Medium
		Temperature	High

Additional Considerations	
Cost	Medium
Maintenance	Medium
Winter Performance	Medium

Variations

- Subsurface storage/infiltration bed
- Use of underdrain
- Use of impervious liner

Key Design Features

- Flexible in size and infiltration
- Ponding depths 6-18 inches for drawdown within 48 hours
- Native plants
- Amend soil as needed
- Provide positive overflow for extreme storm events

Site Factors

- Water table/bedrock separation: two-foot minimum, four foot recommended
- Soils: HSG A and B preferred; C & D may require an underdrain (see Infiltration BMP)
- Feasibility on steeper slopes
- Potential hotspots: Yes with pretreatment and/or impervious liner
- Maximum drainage area: 5:1, not more than 1 acre to one area

Benefits

- Volume control and groundwater recharge, moderate peak rate control, filtration
- Versatile with broad applicability
- Enhance site aesthetics, habitat
- Potential air quality and climate benefits

Limitations

- Higher maintenance until vegetation is established
- Limited impervious drainage area
- Requires careful selection and establishment of plants

Description and Function

Bioretention is a method of managing stormwater by pooling water within a planting area and allowing the water to infiltrate the garden. In addition to managing runoff volume and reducing peak discharge rates, this process filters suspended solids and related pollutants from stormwater runoff. Bioretention can be implemented in small, residential applications or as part of a management strategy in larger applications.

Bioretention is designed into a landscape as a typical garden feature, to improve water quality while reducing runoff quantity. Rain gardens can be integrated into a site with a high degree of flexibility and can integrate nicely with other structural management systems including porous pavement parking lots, infiltration trenches, and other non-structural stormwater BMPs.

Bioretention vegetation serves to filter (water quality) and transpire (water quantity) runoff, and enhance infiltration. Plants absorb pollutants while microbes associated with the plant roots and soil break them down. The soil medium filters out pollutants and allows storage and infiltration of stormwater runoff, providing volume control. In addition, engineered soil media may serve as a bonding surface for nutrients to enhance pollutant removal.

Properly designed bioretention techniques provide a layer of compost that acts like a sponge to absorb and hold runoff. Vegetation in the rain garden can be diverse, through the use of many plant species and types, resulting in a system tolerant to insects, diseases, pollution, and climatic stresses.

The term "rain garden" is used to refer to smaller-scale bioretention facilities typically found on residential properties

Bioretention can accomplish the following:

- Reduce runoff volume
- Filter pollutants, through both soil particles (which trap pollutants) and plant material (which take up pollutants
- Provide habitat
- Recharge groundwater (if no underdrain is placed underneath)
- Reduce stormwater temperature impacts
- Enhance site aesthetics
- Higher maintenance until vegetation is established
- Limited impervious drainage area
- Requires careful selection and establishment of plants

Figure 2 illustrates a schematic of a relatively simple bioretention area (or rain garden). **Figure 3** illustrates a schematic of a bioretention area that is a more technically engineered structure, designed to complete specific stormwater management goals. Pond depth, soil mixture, infiltration bed, perforated underdrains, domed risers, and positive overflow structures may be designed according to the specific, required stormwater management functions.

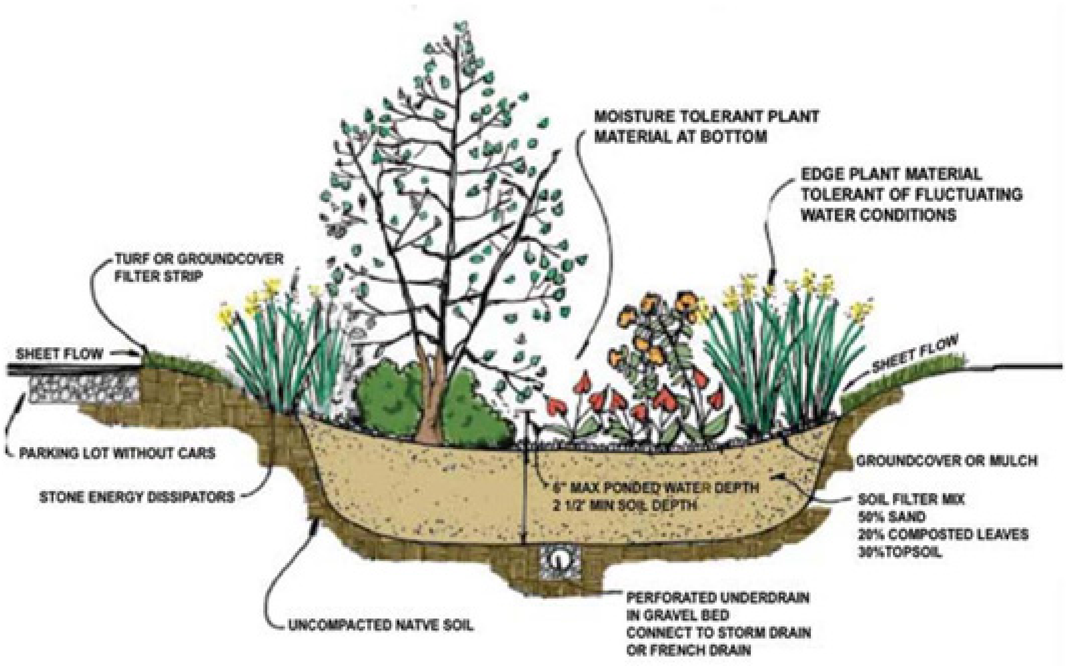

Figure 2 Schematic of a small residential rain garden

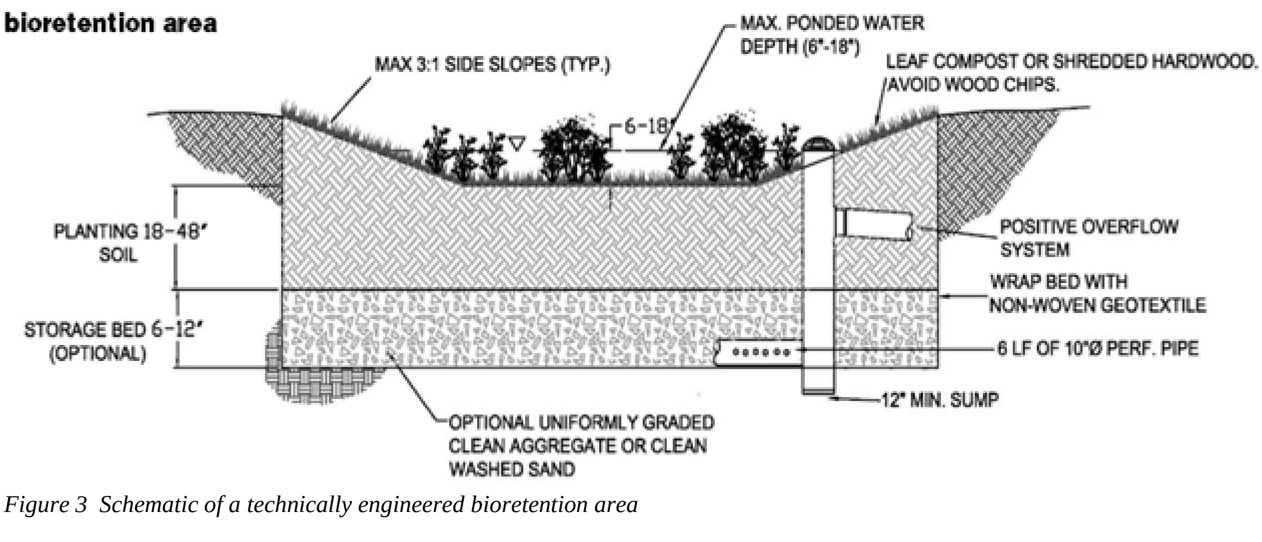

Figure 3 Schematic of a technically engineered bioretention area

Variations

A bioretention system is a depression in the ground planted like a garden that provides for the storage and infiltration of relatively small volumes of stormwater runoff, often managing stormwater on a lot-by-lot basis. This use of many small stormwater controls versus one large detention area promotes the low impact development goal of decentralized treatment of stormwater. But, if greater volumes of runoff must be managed or stored, a bioretention system can be designed with an expanded subsurface infiltration bed, or can be increased in size. Typically, the ratio of impervious area draining to the bioretention area should not exceed five-to-one, and the total impervious area draining to a single system should not be more than one acre. Variations noted relate to performance types, flow entrance, and positive overflow.

Performance types

Depending on varying site conditions, bioretention can be designed to allow for 1) complete infiltration, 2) infiltration/filtration, or 3) filtration. These variations will often determine the need for such design features as the gravel bed, double-walled underdrains, and impervious liners.

Bioretention using complete infiltration occurs in areas where groundwater recharge is beneficial and the soils have the permeability necessary to accommodate the inflow. This type of BMP is often less expensive to construct because there is no underdrain and the soils on site are often used.

The most common variation to this type of bioretention includes a gravel or sand bed underneath the planting bed and often accompanied by the use of a double-walled underdrain. This allows for additional storage or for areas with low permeability to use bioretention as infiltration, as well as, filtration (Figure 3). Some volume reduction will occur through infiltration, as well as evaporation and transpiration.

Another variation is to use bioretention primarily for filtration. This is often used in contaminated soils or hot spot locations using an impervious liner to prevent infiltration and groundwater contamination. The primary stormwater function then becomes filtration with some volume reduction through evaporation and transpiration.

For areas with low permeability, bioretention may achieve some infiltration while acting as detention with peak rate control for all storms up to the design storm.

Flow inlet

Pretreatment of runoff should be provided where sediment or pollutants entering the rain garden may cause concern or decreased BMP functionality. Soil erosion control mats, blankets, or rock must be used where runoff flows from impervious areas enter the rain garden.

Flow inlet: Trench drain

Trench drains can accept runoff from impervious surfaces and convey it to a rain garden. The trench drain may discharge to the surface of the rain garden or may connect directly to an aggregate infiltration bed beneath.

> **Educational Signage**
>
> Once a bioretention area is established, installing signage will help the general public and maintenance crews recognize LID practices, which can help promote sustainable stormwater management. Educational signs can incorporate LID goals and maintenance objectives, in addition to the type of LID project being employed.

Flow inlet: Curbs and curb cuts

Curbs can be used to direct runoff from an impervious surface along a gutter to a low point where it flows into the rain garden through a curb cut. Curb cuts may be depressed curbs, or may be full height curbs with openings cast or cut into them.

Positive overflow

A positive overflow, via the surface or subsurface, is recommended to safely convey excessive runoff from extreme storm events.

Positive overflow: Domed riser

A domed riser may be installed to ensure positive, controlled overflow from the system. Once water ponds to a specified depth, it will begin to flow into the riser through a grate, which is typically domed to prevent clogging by debris.

Positive overflow: Inlet structure

An inlet structure may also be installed to ensure positive, controlled overflow from the system. Once water ponds to a specified depth, it will begin to flow into the inlet.

Applications

Bioretention areas can be used in a variety of applications, from small areas in residential lawns to extensive systems in commercial parking lots (incorporated into parking islands or perimeter areas). Industrial, retrofit, highway/road, and recreational areas can also readily incorporate bioretention. One key constraint in using bioretention in ultra-urban settings is space.

Residential

The residential property owner that wants to design and build a rain garden at home does not need to go through the engineering calculations listed under stormwater calculations and functions. Assistance with simple rain gardens is available from several sources listed under the Plant Selection portion of this BMP. **Figure 4** shows a typical rain garden configuration on a residential property.

Another source of water for a small rain garden is connecting the roof leader from adjacent buildings. The stormwater may discharge to the surface of the bioretention area or may connect directly to an aggregate infiltration bed beneath.

Tree and shrub pits

Tree and shrub pits intercept runoff and provide shallow ponding in mulched areas around the tree or shrub (**Figure 5**). Mulched areas should typically extend to the tree's drip line. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

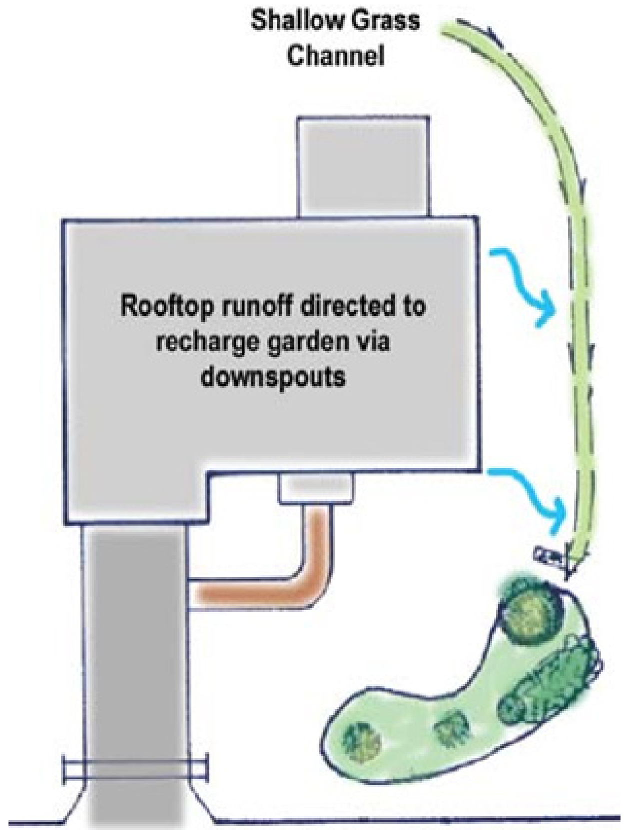

Figure 4 Single-family residential lot drainage schematic Source: Claytor and Schueler, 1995 with modifications by Cahill

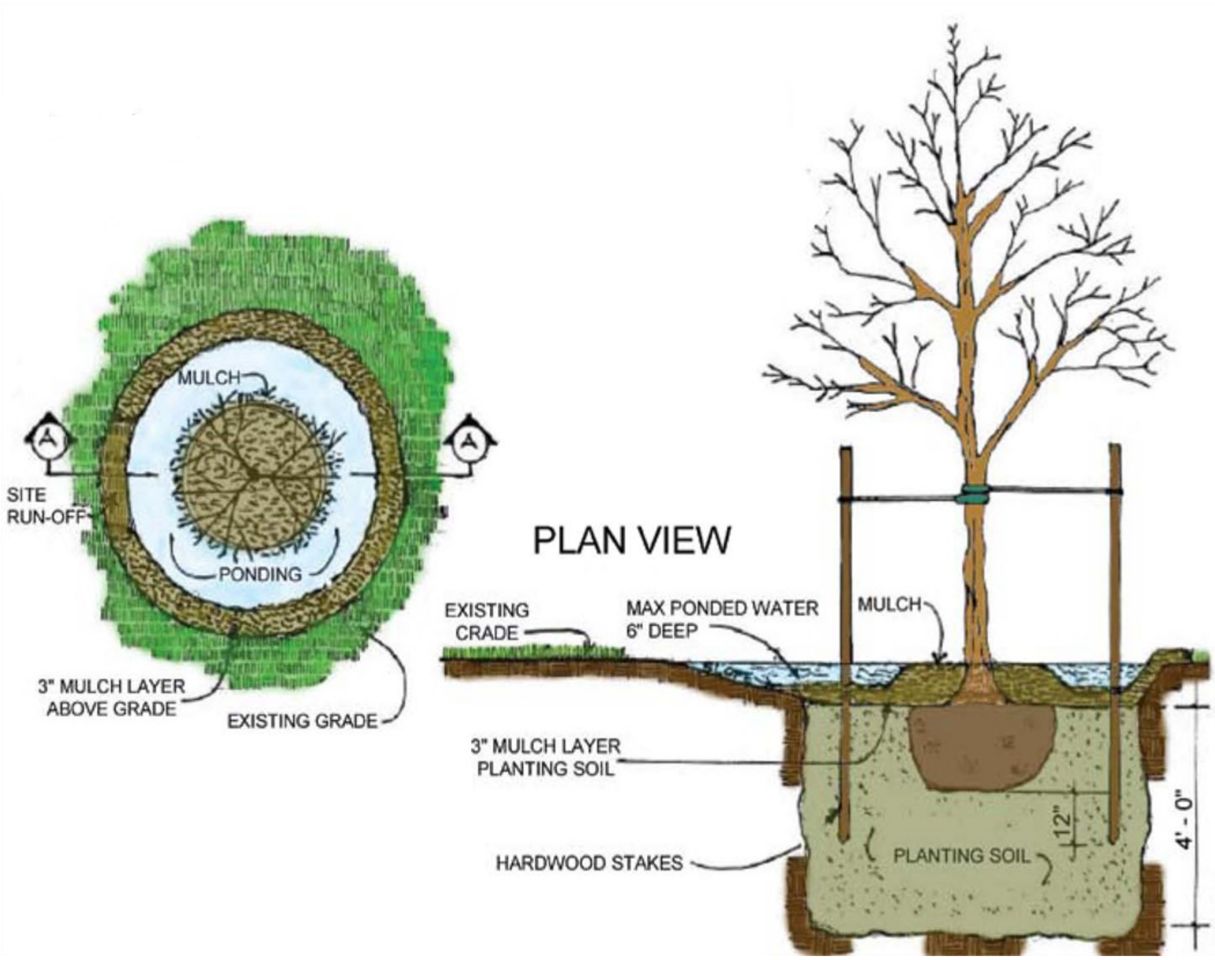

Figure 5 Tree planting detail

Roads and highways

Linear bioretention area feature may be used along a highway. Runoff is conveyed along the concrete curb until it reaches the end of the gutter, where it spills into the vegetated area.

Parking lot island bioretention

In parking lots for commercial, industrial, institutional, and other uses, stormwater management and green space areas are limited. In these situations, bioretention areas for stormwater management and landscaping may provide multiple benefits.

A bioretention area in a parking lot can occur in parking lots with no curbs and with curbs. The no-curb alternative allows stormwater to sheet flow over the parking lot directly into the bioretention area.

In a curbed parking lot, runoff enters the bioretention area through a curb cut. If the runoff volume exceeds the ponding depth available, water overflows the bioretention area and enters a standard inlet.

A variation on this design is a direct underground connection to the standard inlet from the underground aggregate infiltration bed via an overflow pipe.

Primary Components of a Bioretention System

1. Pretreatment (may be necessary to help prevent clogging)
   - Sediment removal through a vegetated buffer strip, cleanout, stabilized inlet, water quality inlet, or sediment trap prior to runoff entry into the bioretention area
2. Flow inlet
   - Varies with site use (e.g., parking island versus residential lot applications)
   - Entering velocities must be non-erosive – use erosion control mats, blankets, or rock where concentrated runoff enters the bioretention area
3. Ponding area
   - Provides temporary surface storage of runoff and allows sediment to settle
   - Provides evaporation for a portion of runoff
   - Depth no more than 6-18 inches for aesthetics, functionality, and safety
4. Plant material (see the Recommended Plant Lists Appendix)
   - Absorbs stormwater through transpiration
   - Root development creates pathways for infiltration
   - Bacteria community resides in the root system creating healthy soil structure with water quality benefits
   - Can improve aesthetics for site
   - Provides habitat for animals and insects
   - Reinforces long-term performance of subsurface infiltration
   - Ensures plants are salt tolerant if in a location that would receive snowmelt chemicals
   - Should be native plant species and placed according to drought and water tolerance
   - Should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix
5. Organic layer or mulch
   - Acts as a filter for pollutants in runoff
   - Protects underlying soil from drying and eroding. Simulates leaf litter by providing environment for microorganisms to degrade organic material
   - Provides a medium for biological growth, decomposition of organic material, adsorption and bonding of heavy metals
   - Wood mulch should be shredded – compost or leaf mulch is preferred
6. Planting soil/volume storage bed
   - Provides water/nutrients to plants
   - Enhances biological activity and encourages root growth
   - Provides storage of stormwater by the voids within the soil particles
   - Provides surface for adsorption of nutrients
7. Positive overflow
   - Provides for the direct discharge of runoff during large storm events when the subsurface/surface storage capacity is exceeded
   - Examples of outlet controls include domed risers, inlet structures, and weirs

Design Considerations

Bioretention is flexible in design and can vary in complexity according to site conditions and runoff volume requirements. Design and installation procedures may vary from very simple for “backyard” rain gardens to highly engineered bioretention areas in ultra-urban areas.

Infiltration BMPs should be sited so that they minimize risk to groundwater quality and present no threat to subsurface structures. **Table 1** provides recommended setback distances of bioretention areas to various lot elements.

The distance from the bottom of the infiltration BMP to the seasonal high groundwater level or bedrock is recommended to be four feet. Two feet is allowable, but may reduce the performance of the BMP.

Setback from	Minimum distance (feet)
Property line	10
Building foundation*	10
Private well	50
Public water supply well**	50
Septic system drainfield***	100

* minimum with slopes directed away from building
** At least 200 feet from Type I or IIa wells, 75 feet from Type IIb and III wells
*** 50 feet for septic systems with a design flow of less than 1,000 gallons per day

Table 1. Recommended Setback Distances

Bioretention is best suited for areas with at least moderate infiltration rates (more than 0.25 inches per hour) – see Infiltration BMP. In extreme situations where permeability is less than 0.25 inches per hour, special variations may apply, such as using amended subsoils or double-walled underdrains (or using constructed wetlands instead). The following procedures should be considered when designing bioretention areas:

1. The **flow entrance** must be designed to prevent erosion in the bioretention area. Some alternatives include flared end sections, erosion control mats, sheet flow into the facility over grassed areas, rock at entrance to bioretention area, curb cuts with grading for sheet flow, and roof leaders with direct surface connection.

2. **A positive overflow system** should be designed to safely convey away excess runoff. The overflow can be routed to the surface in a non-erosive manner or to another stormwater system. Some alternatives include domed risers, inlet structures, weirs, and berms.

3. Sizing criteria
   a. **Surface area** is dependent upon storage volume requirements, but should generally not exceed a maximum loading ratio of 5:1 impervious drainage area to bioretention area and no more than one acre drainage area to one bioretention cell. However, for design purposes, the total volume of water generated from the contributing drainage area must be used, not just the impervious portion. See Infiltration BMP for additional guidance on loading ratios.

      The required bioretention surface area is determined by taking the volume of runoff to be controlled according to LID criteria, and maintaining the maximum ponding depth, loading rate, and emptying time. Infiltration and evapotranspiration are increased by increasing the surface area of the bioretention area. The total surface area needed may be divided into multiple cells. This configuration may be useful to collect runoff from both the front and back of a building.

   b. Surface side slopes should be gradual. For most areas, a maximum of 3:1 side slopes are recommended.

   c. The recommended surface ponding depth is six inches. Up to 18 inches may be used if plant selection is adjusted to tolerate water depth. Drain within 24-48 hours.

   d. **Ponding area** should provide sufficient surface area to meet required storage volume without exceeding the design ponding depth. The subsurface infiltration bed is used to supplement surface storage where appropriate.

4. **Planting soil depth** should generally be between 18 and 48 inches where only herbaceous plant species will be used. If trees and woody shrubs will be used, soil media depth may be increased, depending on plant species. Native soils can be used as planting soil or modified to be suitable on many sites. Small, backyard rain gardens can generally use existing soils without a specialized depth. Planting soil should be approximately four inches deeper than the bottom of the largest root ball.

5. **Planting soil** should be capable of supporting a healthy vegetative cover. Soils should be amended with a composted organic material. A recommended range of a soil mixture is 20-40 percent organic material (compost), 30-50 percent sand, and 20-30 percent topsoil, although any soil with sufficient drainage may be used for bioretention.

   Soils should also have a pH of between 5.5 and 6.5 (better pollutant adsorption and microbial activity), a clay content less than 10 percent (a small amount of clay is beneficial to adsorb pollutants and retain water although no clay is necessary if pollutant loadings are not an issue), be free of toxic substances and unwanted plant material, and have a 5-10 percent organic matter content. Additional organic matter can be added to the soil to increase water holding capacity.

   If brought from off site, **sand** should be clean, coarse, and conform to ASTM C-33 or AASHTO M-6 (Standard Specification for Concrete Aggregates).

   If the void space within an amended soil mix will be used in calculating runoff volume capacity in the system, tests should be conducted on the soil's porosity to determine the available storage capacity.

6. Proper **plant selection** is essential for bioretention areas to be effective. Typically, native floodplain or wet meadow plant species are best suited to the variable environmental conditions encountered in a bioretention area. Suggested species may include Cardinal Flower (*Lobelia cardinalis*), Blue Lobelia (*Lobelia siphilitica*), New England Aster (*Aster novae-angliae*), and Brown Fox Sedge (*Carex vulpinoidea*) (See Recommended Plant Lists Appendix for a detailed list).

   In most cases, seed is not the preferred method for establishing plants in a bioretention area. The fluctuating water levels make it difficult for the seed to readily establish, while the random nature of seeding produces a look which previous experience indicates is unacceptably "wild." Therefore, it is strongly recommended that live plant material in plug or gallon-potted form be used, and installed on 1-2 foot centers for a more formal appearance. Shrubs and trees are also recommended to be included in a bioretention area. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

7. **Planting periods** will vary but, in general, trees and shrubs should be planted from mid-April through early June, or mid-September through mid-November. Native seed should be installed between October 1 and June 1. Live plant material (plugs or gallon pots) should be installed between May 1 and June 15. Planting dates may be lengthened if a regular water source can be provided. Likewise, planting should be ceased at an earlier date in the event of a drought year.

8. A maximum of 2-3 inches of shredded hardwood **mulch,** aged at least six months to one year, or leaf compost (or other comparable product) should be uniformly applied immediately after shrubs and trees are planted to prevent erosion, enhance metal removals, and simulate leaf litter in a natural forest system. Wood chips should be avoided as they tend to float during inundation periods. In order to maintain oxygen flow, mulch or compost should not exceed three

inches in depth or be placed directly against the stems or trunks of plants.

9. When working in areas with **steeper slopes**, bioretention areas should be terraced laterally along slope contours to minimize earthwork and provide level areas for infiltration.

10. A subsurface **storage/infiltration bed**, if used, should be at least six inches deep and constructed of clean gravel with a significant void space for runoff storage (typically 40 percent) and wrapped in geotextile fabric.

11. **Underdrains** are often not needed unless in-situ soils are expected to cause ponding lasting longer than 48 hours. If used, underdrains are typically small diameter (6-12 inches) perforated pipes in a clean gravel trench wrapped in geotextile fabric (or in the storage/infiltration bed). Underdrains should have a flow capacity greater than the total planting soil infiltration rate and should have at least 18 inches of soil/gravel cover. They can daylight to the surface or connect to another stormwater system. A method to inspect and clean underdrains should be provided (via cleanouts, inlet, overflow structure, etc.)

Stormwater Functions and Calculations

When designing a bioretention area, it is recommended to follow a two-step process:

1. Initial sizing of the bioretention area based on the principles of Darcy's Law.
2. Verify that the loading ratio and the necessary volume reductions are being met.

Initial sizing of the bioretention area

Bioretention areas can be sized based on the principles of Darcy's Law, as follows:

With an underdrain:

$$A_f = V * d_f / [k * (h_f + d_f) * t_f]$$

Without an underdrain:

$$A_f = V * d_f / [i * (h_f + d_f) * t_f]$$

Where:

A_f = surface area of filter bed (ft^2)
V = required storage volume (ft^3)
d_f = filter bed depth (ft)
k = coefficient of permeability of filter media (ft/day)
i = infiltration rate of underlying soils (ft/day)
h_f = average height of water above filter bed (ft)
t_f = design filter bed drain time (days)

A "quick check" for sizing the bioretention area is to ignore the infiltration rate and calculate the storage volume capacity of the bioretention area as follows:

A_{inf} = (Area of bioretention area at ponding depth + Bottom area of bioretention area) divided by two = Infiltration area (average area)

The size of the infiltration area is determined by the volume of water necessary to remove as determined by LID criteria, depth of the ponded area (not to exceed 18 inches), infiltration rate of the soil, loading ratio, and, if applicable, any subsurface storage in the amended soil or gravel.

This volume can be considered removed if the bioretention is not underdrained. If the bioretention cell is underdrained, consider the bioretention cell as a detention device with the volume calculated above discharged to a surface water over time t_f.

Verification of meeting volume reduction requirements

The bioretention facility should be sized to accommodate the desired volume reductions towards the required Channel Protection Volume or the required Water Quality Volume, as appropriate (see the Post-Construction Stormwater Quality Management Chapter of the Technical Standards).

The volume of a bioretention area can have three components: surface storage volume, soil storage volume, and infiltration bed volume. These three components should be calculated separately and added together. The goal is that this total volume is larger than the required Channel Protection Volume or the Water Quality Volume, as appropriate. If the total volume is less than the required volume, another adjustment may be needed to the bioretention area (e.g., increased filter bed depth).

Total volume calculation:

1. Surface storage volume (ft^3) = Average bed area (ft^2) * Maximum design water depth (ft)
2. Soil storage volume (ft^3) = Infiltration area (ft^2) * Depth of amended soil (ft) * Void ratio of amended soil.
3. Subsurface storage/Infiltration bed volume (ft^3) = Infiltration area (ft^2) * Depth of underdrain material (ft) * Void ratio of storage material

Total bioretention volume = Surface storage volume + Soil storage volume (if applicable) + Infiltration bed volume (if applicable).

Peak rate mitigation

The discussion under LID Approach in Post-Construction Stormwater Quality Management Chapter of the Technical Standards provides information on methodology to account for the provided distributed storage for the purpose of calculating the required detention pond size for peak rate control. If an underdrain is required, the bioretention also acts as a detention practice with a discharge rate roughly equal to the infiltration rate of the soil multiplied by the average bed area. The discharge rate should be counted towards the site's allowable release rate (if not leading to the site's detention pond) or as inflow to the site's detention pond (if an underdrain would eventually empty into the site's detention pond).

Water Quality Improvement

The reported water quality benefits of bioretention can be expected to remove a high amount of total suspended solids (typically 70-90 percent), a medium amount of total phosphorus (approximately 60 percent), and a medium amount of total nitrogen (often 40-50 percent). In areas with high sediment loading, pretreatment of runoff can significantly reduce the amount of bioretention maintenance required (See discussion in the Post-Construction Stormwater Quality Management Chapter of the Technical Standards for water quality calculation procedures).

Construction Guidelines

The following is a typical construction sequence (Note for all construction steps: Erosion and sediment control methods need to adhere to the construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM's Soil Erosion and Sedimentation Control (Rule 5) Program).

1. Complete site grading, minimizing compaction as much as possible. If applicable, construct curb cuts or other inflow entrance, but provide protection so that drainage is prohibited from entering the bioretention construction area. Construct pre-treatment devices (filter strips, swales, etc.) if applicable.

2. Subgrade preparation

   a. Existing subgrade in rain gardens should not be compacted or subject to excessive construction equipment traffic. Loads on the subgrade should not exceed four pounds per square inch.
   b. Initial excavation can be performed during rough site grading, but should not be carried to within one foot of the final bottom elevation. Final excavation should not take place until all disturbed areas in the drainage area have been stabilized.
   c. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding in the graded bottom, this material should be removed with light equipment and the underlying soils scarified to a minimum depth of six inches with a york rake or equivalent by light tractor.
   d. Bring subgrade of bioretention area to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas should be level grade on the bottom.

3. Stabilize grading except within the bioretention area. Bioretention areas may be used as temporary sediment traps, provided the proposed finish elevation of the bed is at

least 12 inches lower than the bottom elevation of the sediment trap (if used as such, all accumulated material and at least 12 inches of soil should be removed).

4. Excavate bioretention area to proposed invert depth and scarify the existing soil surfaces. Do not compact soils.

5. Backfill bioretention area with amended soil as shown on plans and specifications. Overfilling is recommended to account for settling. Light hand tamping is acceptable if necessary.

6. Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch, or topsoil as specified on plans.

7. Bioretention area/rain garden installation

   a. Upon completing subgrade work, notify the engineer to inspect at his/her discretion before proceeding with bioretention installation.
   b. For the subsurface storage/infiltration bed installation, amended soils should be placed on the bottom to the specified depth.
   c. Planting soil should be placed immediately after approval of subgrade preparation/bed installation. Any accumulation of debris or sediment that takes place after approval of subgrade should be removed prior to installation of planting soil at no extra cost to the owner.
   d. If called for in the design, install approved planting soil in 18-inch maximum lifts and lightly compact (tamp with backhoe bucket or by hand). Keep equipment movement over planting soil to a minimum – **do not over-compact**. Install planting soil to grades indicated on the drawings. Loads on the soil should not exceed four pounds per square inch.
   e. Presoak the planting soil at least 24 hours prior to planting vegetation to aid in settlement.
   f. Plant trees and shrubs according to supplier's recommendations and only from mid-March through the end of June or from mid-September through mid-November.
   g. Install two or three inches of shredded hardwood mulch (minimum age six months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.
   h. Protect rain gardens from sediment at all times during construction. Compost socks, diversion berms, and/or other appropriate measures should be used at the toe of slopes that are adjacent to rain gardens to prevent sediment from washing into these areas during site development.
   i. When the site is <u>fully vegetated</u> and the soil mantle stabilized, notify the plan designer to inspect the rain garden drainage area at his/her discretion before the area is brought online and sediment control devices removed.

8. Mulch and install erosion protection at surface flow entrances where necessary.

Maintenance

Properly designed and installed bioretention areas require some regular maintenance, most within the first year or two of establishment. Less maintenance is required when the native perennial vegetation becomes established.

1. Water vegetation at the end of each day for two weeks after planting is completed. Newly established plants should continue to receive approximately one inch of water per week throughout the first season, or as determined by the landscape architect.

2. While vegetation is being established, pruning and weeding may be required. Weeds should be removed by hand.

3. Organic material may also need to be removed approximately twice per year (typically by hand).

4. Perennial plantings may be cut down at the end of the growing season to enhance root establishment.

5. Mulch should be re-spread when erosion is evident and replenished once every one to two years or until the plants begin to fill in the area and the space between plants is minimized.

6. Bioretention area should be inspected at least two times per year for sediment buildup, erosion, and to evaluate the health of the vegetation. If sediment buildup reaches 25 percent of the ponding depth, it should be removed. If erosion is noticed within the bioretention area, additional soil stabilization measures should be applied. If vegetation appears to be in poor health with no obvious cause, a landscape specialist should be consulted.

7. Bioretention vegetation may require watering, especially during the first year of planting. Ensure the maintenance plan includes a watering schedule for the first year, and in times of extreme drought after plants have been established.

8. Bioretention areas should not be mowed on a regular basis. Trim vegetation as necessary to maintain healthy plant growth.

Planting Tip

When planting your bioretention area, it is usually helpful to mark the different planting areas. An effective method is using spray paint and flags to mark designated areas. This is especially helpful when utilizing volunteers.

Winter Considerations

Use salt-tolerant vegetation where significant snowmelt containing deicing chemicals is expected. The use of sand, cinders, and other winter abrasives should be minimized. If abrasives are used, additional maintenance may be required to remove them in the spring. Bioretention soils can be expected to resist freezing and remain functioning for most of the year (although biological pollutant removal processes will be reduced during winter). Bioretention areas can even be used for snow storage assuming this will not harm the vegetation. Pipes, inlets, overflow devices, and other stormwater structures associated with bioretention should be designed according to general guidance on cold climate construction.

Cost

Bioretention areas often replace areas that were intensively landscaped and require high maintenance. In addition, bioretention areas can decrease the cost for stormwater conveyance systems on a site. Bioretention areas cost approximately $5-7 per cubic foot of storage to construct.

Designer/Reviewer Checklist for Rain Gardens/Bioretention

Item	Page No.	Yes	No	N/A	Notes
Was Soil infiltration Testing Protocol Appendix followed?*					
Appropriate areas of the site evaluated?	--				
Infiltration rates measured? ➢ *Moderate infiltration rates: > 0.25 inches/hour. If < 0.25 inches/hour, special variations may apply – such as using amended subsoils or underdrains.*	8				
Were the bioretention design guidelines followed?					
Minimum 2-foot separation between the bed bottom and bedrock/ SHWT?	8				
Soil permeability acceptable?	8				
If not, appropriate underdrain provided? ➢ *6-12 inches in diameter; perforated pipes*	10				
Natural, uncompacted soils?	11				
Level infiltration area (bed bottom)?	11				
Excavation in rain garden areas minimized?	--				
Hotspots/pretreatment considered?	1				
Loading ratio below 5:1 (described in infiltration BMP)?	8				
Ponding depth limited to 18 inches?	1,7,8				
Drawdown time less than 48 hours?	1				
Positive overflow from system?	7,8				
Erosion and Sedimentation control?	12				
Feasible construction process and sequence?	11,12				
Entering flow velocities non-erosive or erosion control devices?	7,8				
Acceptable planting soil specified? ➢ *20-40% organic material (compost), 30-50% sand, 20-30% topsoil)*	9				

* In general, the protocol should be followed as much as possible.

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

CAPTURE REUSE

Structures designed to intercept and store runoff from rooftops allow for its reuse, reducing volume and overall water quality impairment. Stormwater is contained in the structures and typically reused for irrigation or other water needs.

Figure 1 Above ground cistern, Chicago, IL (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	High
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Low*
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Med
Highway/Road	No	TP	Med
Recreational	Yes	NO_3	Med
		Temperature	Med

* *Depends on site design*

Additional Considerations	
Cost • Rain Barrel • Cistern • Manufactured product	 Low Med Varies
Maintenance	Med
Winter Performance	Med

Variations

- Rain barrels
- Cisterns, both underground and above ground
- Tanks
- Storage beneath a surface (using manufactured products)

Key Design Features

- Small storm events are captured with most structures
- Provide overflow for large storm events
- Discharge water before next storm event
- Consider site topography, placing structure up-gradient in order to eliminate pumping needs

Site Factors

- Water table to bedrock depth: N/A (although must be considered for subsurface systems
- Soils: N/A
- Slope: N/A
- Potential hotspots: Yes, with treatment
- Maximum drainage area: N/A

Benefits

- Provides supplemental water supply
- Wide applicability
- Reduces potable water use
- Related cost savings and environmental benefits

Limitations

- Manages only relatively small storm events which requires additional management and use for the stored water

Description and Function

Capture reuse is the practice of collecting rainwater in a container and reusing it in the future. Other terms for this BMP include *storage/reuse, rainwater harvesting, and rainwater catchment system*.

This structural BMP reduces potable water needs while simultaneously reducing stormwater discharges. When rain barrels or cisterns are full, rooftop runoff should be directed to drywells, planters, or bioretention areas where it will be infiltrated.

Variations

Rain Barrels

Commonly, rooftop downspouts are connected to a rain barrel that collects runoff and stores water until needed for a specific use. Rain barrels are often used at individual homes where water is reused for garden irrigation, including landscaped beds, trees, or other vegetated areas. Other uses include commercial and institutional facilities where the capacity of stormwater can be captured in smaller volume rain barrels.

Cisterns

A cistern is a container or tank that has a greater storage capacity than a rain barrel. Typically, cisterns are used to supplement greywater needs (i.e., toilet flushing, or some other sanitary sewer use), though they can also be used for irrigation. Cisterns may be comprised of fiberglass, concrete, plastic, brick, or other materials and can be located either above or below ground. The storage capacity of cisterns can range from 200 gallons to 10,000 gallons. Very large cisterns, essentially constructed like an underground parking level, can also be used. **Figure 2** highlights the typical components of a cistern.

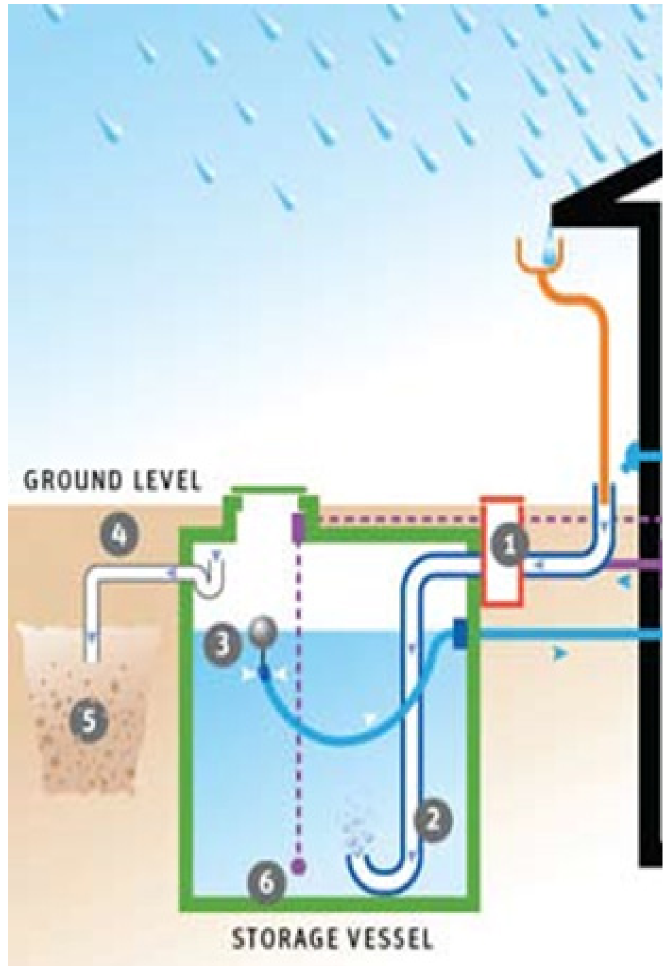

Figure 2 Typical cistern components
Source: This image generously provided by [*www.rainkeeper.us*](www.rainkeeper.us)

Figure Description:

1. Filter/screening mechanism to filter runoff
2. Inflow into cistern
3. Intake for water use
4. Cistern overflow
5. Subsequent stormwater system (infiltration system in this case) for cistern overflow
6. Optional level gauge

Vertical storage

A vertical storage container is a structure designed to hold a large volume of stormwater drained from a large impervious area and is the largest of the capture reuse containers. The use of these structures is a function of drainage area and water needs. Vertical structures are best used for intensive irrigation needs or even fire suppression requirements, and should be designed by a licensed professional. These storage systems can be integrated into commercial sites where water needs may be high.

Storage beneath structure

Stormwater runoff can be stored below ground under pavement and landscaped surfaces through the use of structural plastic storage units and can supplement onsite irrigation needs. These structures can provide large storage volumes without the need for additional structural support from the building.

Designing a capture reuse system in which the storage unit is underground is best used in institutional or commercial settings. This type of subsurface storage is larger, more elaborate, typically designed by a licensed professional, and requires pumps to connect to the irrigation system.

Applications

Capture reuse containers can be used in urbanized areas where the need for supplemental onsite irrigation or other high water use exists. Areas that would benefit from using a capture reuse container include:

- Parking garage,
- Office building,
- Residential home or building, and
- Other building use (commercial, light industrial, institutional, etc.).

Design Considerations

Design and installation procedures for capture reuse containers can vary from simple residential rain barrels to highly engineered underground systems in ultra-urban areas. **Table 1** provides general information on cistern holding capacity. The following procedures should be considered when designing sites with capture reuse containers.

Height (feet)	6-foot Diameter	12-foot Diameter	18-foot Diameter
6	1,269	5,076	11,421
8	1,692	6,768	15,227
10	2,115	8,460	19,034
12	2,538	10,152	22,841
14	2,961	11,844	26,648
16	3,384	13,535	30,455
18	3,807	15,227	34,262
20	4,230	16,919	38,069

Table 1 Round Cistern Capacity (Gallons)
Source: The Texas Manual on Rainwater Harvesting

1. Identify opportunities where water can be reused for irrigation or indoor greywater reuse and then calculate the water need for the intended uses. For example, if a 2,000 square foot landscaped area requires irrigation for four months in the summer at a rate of one inch per week, the designer must determine how much water will be needed to achieve this goal (1,250 gallons per week, approximately 22,000 gallons for the season), and how often the storage unit will be refilled with precipitation. The usage requirements and the expected rainfall volume and frequency must be determined.

2. Rain barrels and cisterns should be positioned to receive rooftop runoff.

3. If cisterns are used to supplement greywater needs, a parallel conveyance system must be installed to separate greywater from other potable water piping systems. Do not connect to domestic or commercial potable water system.

4. Consider household water demands (**Table 2**) when sizing a system to supplement residential greywater use.

Fixture	Use	Flow Rate
Toilet	# flushes per person per day	1.6 gallons per flush (new toilet)
Shower	# minutes per person per day (5 minutes suggested max.)	2.75 gallons per minute (restricted flow head)
Bath	# baths per person per day	50 gallons per bath (average)
Faucets	Bathroom and kitchen sinks	10 gallons per day
Washing Machine	# loads per day	50 gallons per load (average)
Dishwasher	# loads per day	9.5 gallons per load

Table 2 Household Water Demand Chart
Source: Philadelphia Stormwater Manual

5. Discharge points and storage units should be clearly marked "Caution: Untreated Rainwater, Do Not Drink."

6. Screens should be used to filter debris from runoff flowing into the storage units. Screens should be made of a durable, non-corrodible material and be easily maintainable.

7. Protect storage elements from direct sunlight by positioning and landscaping. Limit light into devices to minimize algae growth.

8. The proximity to building foundations should be considered for overflow conditions. The minimum setback distance for capture and reuse systems is 10 feet.

9. If the capture and reuse system or any elements of the system are exposed to freezing temperatures, then it should be emptied during the winter months to prevent ice damage.

10. Cisterns should be watertight (joints sealed with nontoxic waterproof material) with a smooth interior surface.

11. Covers and lids should have a tight fit to keep out surface water, insects (mosquitoes), animals, dust, and light.

12. Release stored water between storm events for the necessary storage volume to be available.

13. Positive outlet for overflow should be provided a few inches from the top of the cistern and sized to safely discharge the appropriate design storms when the cistern is full.

14. Rain barrels require a release mechanism in order to drain empty between storm events. Connect a soaker hose to slowly release stored water to a landscaped area.

15. Observation risers should be at least six inches above grade for buried cisterns.

16. Reuse may require pressurization. Water stored has a pressure of 0.43 psi per foot of water elevation. A 10-foot tank when full would have a pressure of 4.3 psi (0.43*10). Most irrigation systems require at least 15 psi. To add pressure, a pump, pressure tank, and fine mesh filter can be used. While this adds to the cost of the system, it makes the system more versatile and therefore practical.

17. Capture/reuse can also be achieved using a subsurface storage reservoir which provides temporary storage of stormwater runoff for reuse. The stormwater storage reservoir may consist of clean uniformly graded aggregate and a waterproof liner or pre-manufactured structural stormwater storage units.

Stormwater Functions and Calculations

Volume reduction

In order to keep storage costs to a minimum, it makes sense to size the storage tank so that it does not greatly exceed the water need. Where this is done, especially where a high-volume demand greatly exceeds runoff (e.g., irrigation or industrial makeup water), runoff volume reduction for a particular storm can be assumed to equal the total volume of storage.

Where the captured water is the sole source for a particular operation (e.g., flushing toilets), the user does not want the stored water to be depleted before the next runoff event that replenishes it. In that case, the appropriate volume to store will be relatively easy to calculate based on the daily water need. After water need is determined, choose which structure will be large enough to contain the amount of water needed. The amount replenished by a particular storm is equal to the volume reduction.

Additional Volume Reduction Considerations

For storage vessels that are not drained down completely before the next runoff event, the volume available to be filled by a particular storm may be difficult to calculate. Typical LID sizing criteria is based on the volume that goes to storage during a particular storm. That volume can be subtracted from the runoff volume, and the designer/developer can size the storage unit to achieve the targeted volume reduction. But sizing criteria under these capture and reuse circumstances may become need based. The designer/builder may estimate the volume removal for a particular storm, but estimates should be realistic given the use rate and storm runoff frequency. The estimate can be based on an average available storage capacity or preferably on a water balance analysis based on actual rainfall statistics.

Available Volume for Capture (gallons) = Runoff Coefficient (unitless) * Precipitation (inches) * Area (ft^2) * 1 foot/12 inches * 7.4805 gallons/ft^3

OR

$$V = 0.62 * C * P * A$$

Where:

V = available volume for capture (gallons)
0.62 = unit conversion (gal/in./ft^2)
C = volumetric runoff coefficient (unitless), typically 0.9 to 0.95 for impervious areas
P = precipitation amount (inches)
A = drainage area to cistern (ft^2)

Sizing the tank is a mathematical exercise that balances the available collection (roof) area, annual rainfall, intended use of rainwater and cost. In other words, balance what can be collected against how the rainwater will be used and the financial and spatial costs of storing it. In most areas of the country, it's possible to collect 80 percent of the rain that falls on the available roof area. The 20 percent reduction accounts for loss due to mist and heavy storms that release more rain than the tank can accommodate. That level of capture would yield approximately 500 gallons per inch of rain per 1000 SF of capture area. **Table 3** includes available capture volumes based on drainage area and annual rainfall.

Note: Although utilization of Capture Reuse BMP is beneficial and encouraged, no runoff reduction recognition is considered for this practice towards the required Channel Protection Volume or Water Quality Volume discussed under LID Approach in Post-Construction Stormwater Quality Management Chapter of Technical Standards.

Peak rate mitigation

Overall, capture and reuse takes a volume of water out of site runoff and puts it back into the ground. This reduction in volume will translate to a lower overall peak rate for the site.

Water quality improvement

Pollutant removal takes place through filtration of recycled primary storage, and/or natural filtration through soil and vegetation for overflow discharge. Quantifying pollutant removal will depend on design. Sedimentation will depend on the area below the outlet that is designed for sediment accumulation, time in

Annual Rainfall Yield in Gallons for Various Impervious Surface Sizes and Rainfall Amounts								
Impervious Surface Area (ft^2)	Rainfall (inches)							
	26	28	30	32	34	36	38	40
200	3,079	3,316	3,553	3,790	4,027	4,264	4,501	4,738
400	6,159	6,633	7,106	7,580	8,054	8,528	9,002	9,475
600	9,238	9,949	10,660	11,370	12,081	12,792	13,502	14,213
800	12,318	13,265	14,213	15,160	16,108	17,056	18,003	18,951
1,000	15,397	16,582	17,766	18,951	20,135	21,319	22,504	23,688
1,200	18,477	19,898	21,319	22,741	24,162	25,583	27,005	28,426
1,400	21,556	23,214	24,873	26,531	28,189	29,847	31,505	33,164
1,600	24,636	26,531	28,426	30,321	32,216	34,111	36,006	37,901
1,800	27,715	29,847	31,979	34,111	36,243	38,375	40,507	42,639
2,000	30,795	33,164	35,532	37,901	40,270	42,639	45,008	47,377
2,200	33,874	36,480	39,086	41,691	44,297	46,903	49,508	52,114
2,400	36,954	39,796	42,639	45,481	48,324	51,167	54,009	56,852
2,600	40,033	43,113	46,192	49,272	52,351	55,431	58,510	61,589
2,800	43,113	46,429	49,745	53,062	56,378	59,694	63,011	66,327
3,000	46,192	49,745	53,299	56,852	60,405	63,958	67,512	71,065
3,200	49,272	53,062	56,852	60,642	64,432	68,222	72,012	75,802
3,400	52,351	56,378	60,405	64,432	68,459	72,486	76,513	80,540
3,600	55,431	59,694	63,958	68,222	72,486	76,750	81,014	85,278
3,800	58,510	63,011	67,512	72,012	76,513	81,014	85,515	90,015

Table 3 Annual Rainfall yield (in gallons) for impervious surfaces

storage, and maintenance frequency. Filtration through soil will depend on flow draining to an area of soil, the type of soil (infiltration capacity), and design specifics (stone bed, etc.).

Maintenance

Rain Barrels

- Inspect rain barrels four times per year, and after major storm events.
- Remove debris from screen as needed.
- Replace screens, spigots, downspouts, and leaders as needed.
- To avoid damage, drain container prior to winter, so that water is not allowed to freeze in devices.

Cisterns

- Flush cisterns annually to remove sediment.
- Brush the inside surfaces and thoroughly disinfect twice per year.
- To avoid damage, drain container prior to winter, so that water is not allowed to freeze in devices.

Cost

Both rain barrels and cisterns are assumed to have a life span of 25 years. **Table 4** shows typical costs for rain barrels and cisterns.

	Capacity	Cost Range
Rain barrel	40-75 gal.	\$100-\$250
Cistern	200-10,000 gal.	Varies by manufacturer and material
Vertical storage	64-12,000 gal	\$100-\$11,000

Table 4 Capacities and Costs

Designer/Reviewer Checklist for Capture Reuse

Type and size (gallons) of storage system provided: ____

ITEM*	Page No.	YES	NO	N/A	NOTES
Capture area defined and calculations performed?	5,6				
Pretreatment provided to prevent debris/sediment from entering storage system?	4				
Water use identified and calculations performed?	3,4				
If the use is seasonal, has off-season operation been considered?	--				
Draw-down time considered?	--				
Is storage system located optimally for the use?	--				
Is a pump required?	--				
If so, has an adequate pump system been developed?	4				
Acceptable overflow provided?	4				
Winter operation (protection from freezing) considered?	4,6				
Observation/clean-out port provided?	4				
Maintenance accounted for and plan provided?	6				

* *These items primarily relate to larger systems, not residential rain barrels*

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BMP Fact Sheet

CONSTRUCTED FILTER

Constructed filters are structures or excavated areas containing a layer of sand, compost, organic material, peat, or other media that reduce pollutant levels in stormwater runoff by filtering sediments, metals, hydrocarbons, and other pollutants. Constructed filters are suitable for sites without sufficient surface area available for bioretention.

Figure 1 Constructed filter, Portland, OR (City of Portland 2004 Stormwater Management Manual)

Applications		Stormwater Quantity Functions	
Residential	Limited	Volume	Low/High*
Commercial	Yes	Groundwater Recharge	Low/High*
Ultra Urban	Yes	Peak Rate	Low/High*
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	High**
Highway/Road	Yes	TP	Medium**
Recreational	Yes	TN	Medium**
		Temperature	Low

Additional Considerations	
Cost	Med/High
Maintenance	High
Winter Performance	Medium

** Function is low without infiltration and increases when infiltration is provided*
*** Sand filters only (For filters with infiltration, see Subsurface Infiltration Bed section, or other infiltration BMP sections. For manufactured systems, see manufacturer's information, as well as results from independent verification.)*

Variations

- Surface non-vegetated
- Vegetated
- Infiltration
- Contained
- Linear perimeter
- Small subsurface
- Large subsurface
- Manufactured filtration systems

Key Design Features

- Depth of filtering medium 18-30"
- Surface ponding should drain down within 72 hours (3-6" ponding depth)
- May be designed to infiltrate
- May require pretreatment for debris and sediment
- Some systems require sufficient head (2-6 feet)
- Flow splitter or positive overflow required to bypass large storms
- Requires minimum permeability of filtration medium
- Underdrains may be needed if infiltration is infeasible

Site Factors

- Water table to bedrock depth: N/A
- Soils: N/A
- Slope: N/A
- Potential hotspots: Yes
- Maximum drainage area: N/A

Benefits

- Good water quality performance
- Lots of variations for a variety of applications
- Can be used effectively as pretreatment for other BMPs

Limitations

- Limited water quantity benefits
- Relatively high cost
- High maintenance needs

Description and Function

A constructed filter is a structure or excavation filled with material that filters stormwater runoff to remove particulate matter and the pollutants attached to it. The filter media may be comprised of materials such as sand, peat, compost, granular activated carbon (GAC), perlite, or inorganic materials. In some applications, the stormwater runoff flows through an unfilled "pretreatment" chamber to allow the large particles and debris to settle out. Surface vegetation is another good option for pretreatment, as long as it is extensive enough to protect the filter from sediment during large storm events. The runoff then passes through the filter media where additional pollutants are filtered out, and is collected in an underdrain and returned to the conveyance system, receiving waters, or infiltrated into the soil. In general, constructed filters are best applied at sites without sufficient surface area available for bioretention.

Variations

There are a wide variety of constructed filter applications, including surface and subsurface, vegetated, and with or without infiltration. There are also a variety of manufactured filter products that may be purchased (see water quality devices BMP). In general, constructed filters consist of some, if not all, of the following components: excavation or container for media, pretreatment, flow entrance/inlet, surface storage (ponding area), filter media, underdrain (if necessary), and positive overflow. Examples of these variations include:

- Surface non-vegetated filter,
- Surface vegetated filter,
- Surface contained filter,
- Surface linear "perimeter" filter,
- Small subsurface filter, and
- Large subsurface filter.

Surface Infiltration Filter

Filters may be designed to allow some or all of the treated water to infiltrate. Infiltration design criteria apply for all filters designed (**Figure 2**) with infiltration. In all cases, a positive overflow system is recommended.

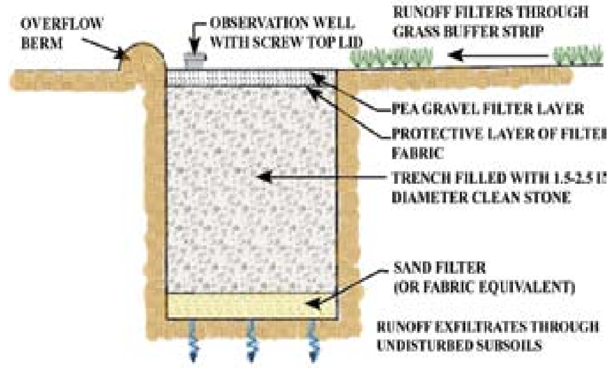

Figure 2 Filter with infiltration to subsoils

Surface non-vegetated filter

A surface non-vegetated filter is constructed by excavation or by use of a structural container. The surface may be covered in gravel, sand, peat, river stone, or similar material.

Surface vegetated filter

A layer of vegetation is planted on top of the filtering medium (**Figure 3**). Compost-amended soil may serve as a filter medium. (See soil restoration BMP for precautions about compost materials, to prevent exporting phosphorus from the filter.) For filters composed of filtering media such as sand (where topsoil is required for vegetation), a layer of nonwoven, permeable geotextile should separate the topsoil and vegetation from the filter media.

Surface contained filter

In contained filters, infiltration is not incorporated into the design. Contained filters may consist of a physical structure, such as a precast concrete box, or they may be excavated chambers or trenches. For excavated contained filters, an impermeable liner is added to the bottom of the excavation to convey the filtered runoff downstream.

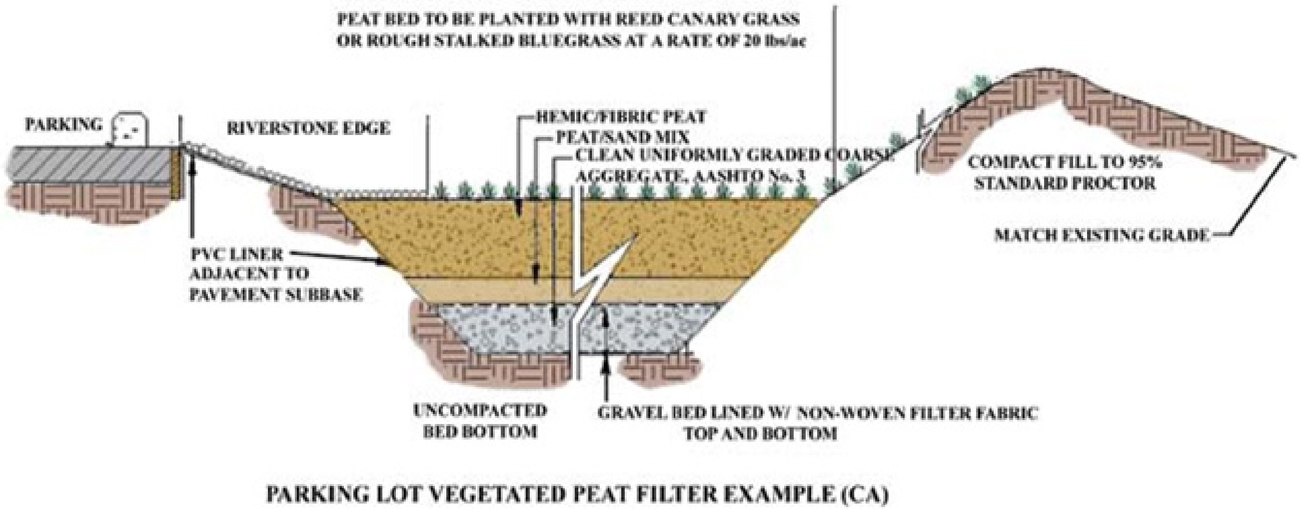

Figure 3 Vegetated peat filter adjacent to a parking lot

Surface linear "perimeter" filter

Perimeter filters may consist of enclosed chambers (such as trench drains) that run along the perimeter of an impervious surface. Perimeter filters may also be constructed by excavation, and be vegetated. All perimeter filters must be designed with the necessary filter medium and sized in accordance with the drainage area.

Small subsurface filter

A small subsurface filter (**Figure 4**) is an inlet designed to treat runoff at the collection source. Small subsurface filters are useful for hot spot pretreatment and are similar in function to water quality inlets/inserts. Small subsurface filters must be carefully designed and maintained so that runoff is directed through the filter media (see Design Considerations).

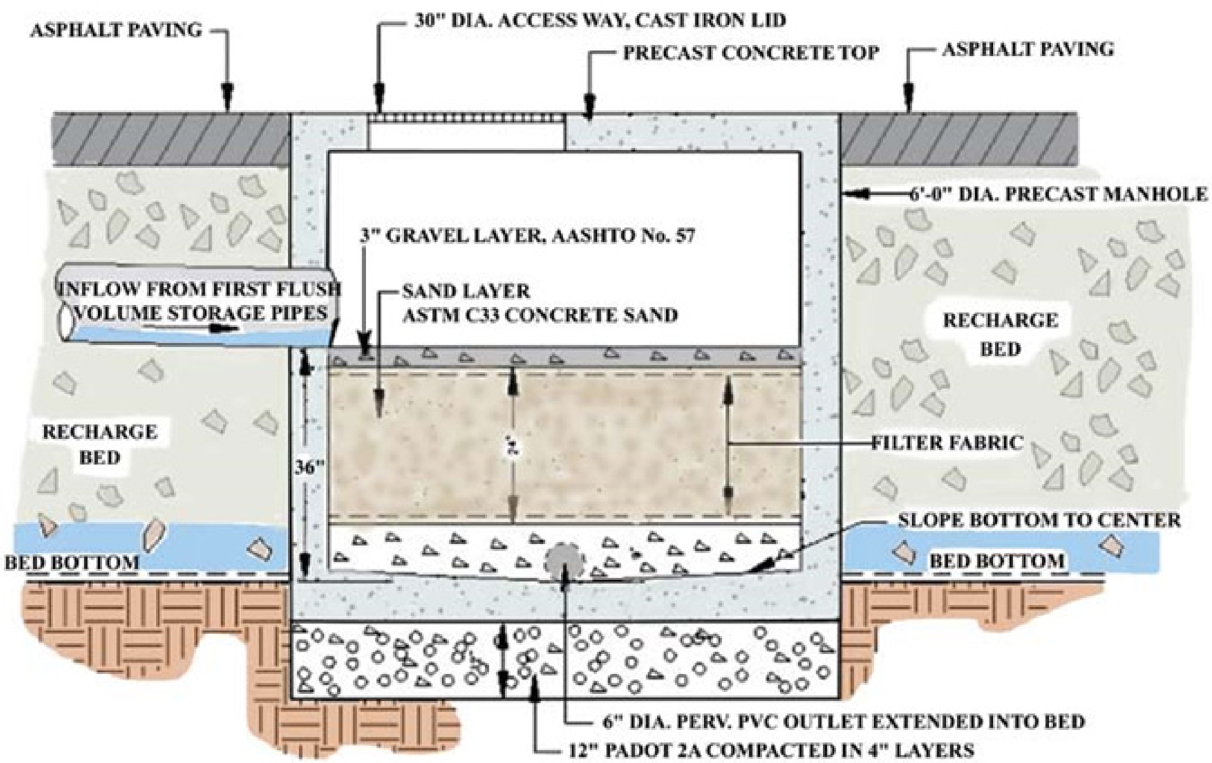

Figure 4 Small subsurface filter
Source: Pennsylvania Stormwater BMP Manual

Large subsurface filter

Large subsurface filters (**Figure 5**) receive relatively large amounts of flow directed into an underground box that has separate chambers. One chamber settles large particles, and the other chamber contains media to filter small particles. The water discharges through an outlet pipe and into the stormwater system.

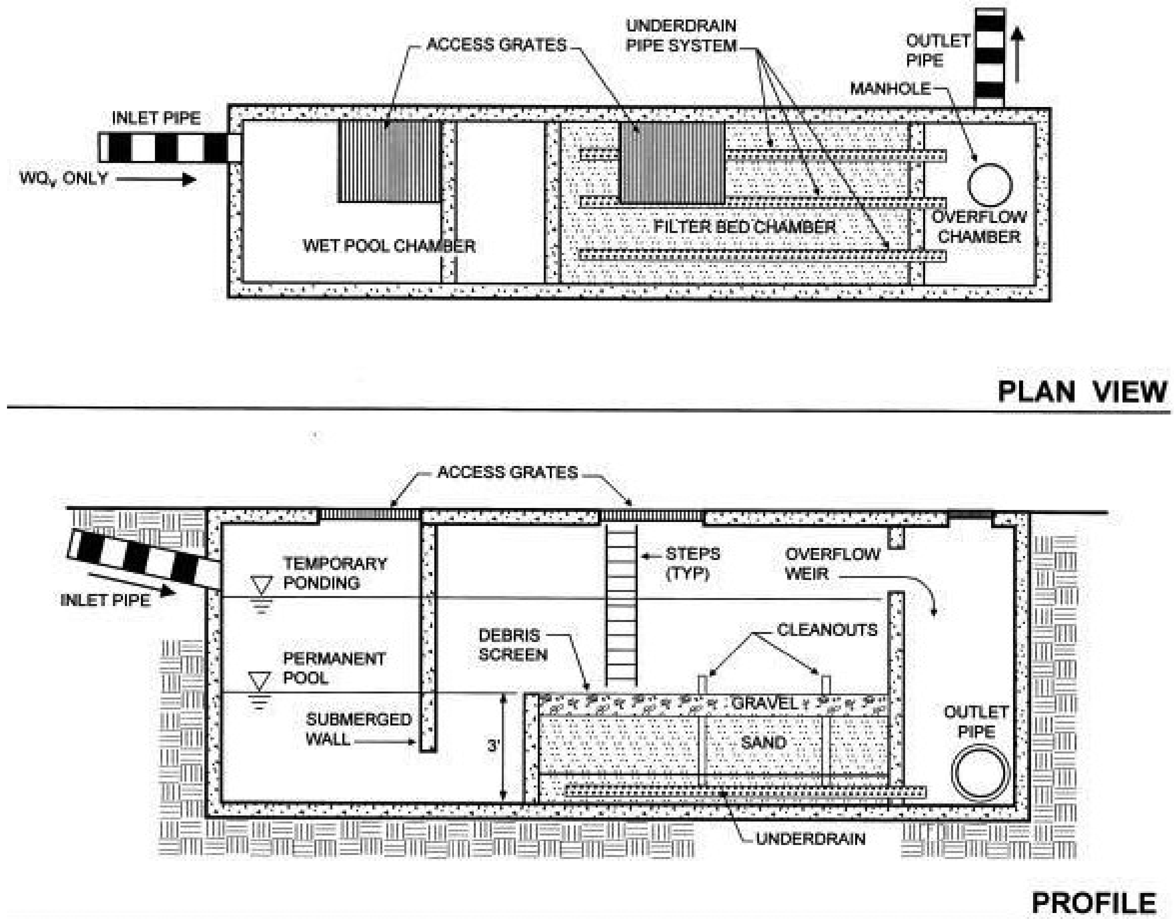

Figure 5 Large subsurface filter
Source: New York Stormwater BMP Manual

Applications

Constructed filters can be used in a wide variety of applications, from commercial/industrial developments to ultra-urban sites and even transportation projects. Their application in residential settings, especially low-density residential, can be limited because they require extensive maintenance. Moreover, other BMPs are more cost effective for stormwater management in residential projects (constructed filters are generally used for areas with high impervious cover).

Filters are applicable in urban areas of high pollutant loads and are especially applicable where there is limited area for constructing BMPs. Filters may be used as a pretreatment BMP for other BMPs such as wet ponds or infiltration systems, but input to many filters also requires pretreatment to reduce large settled particulates or debris.

Filters may be used in hot spot areas for water quality treatment, and spill containment capabilities may be incorporated into a filter. Examples of typical areas that benefit from the use of a constructed filter include:

- Parking lots,
- Roadways and highways,

- Light industrial sites,
- Marina areas,
- Transportation fueling and maintenance facilities,
- Fast food and shopping areas,
- Waste transfer stations, and
- Urban streetscapes.

Design Considerations

1. All constructed filters must be designed so that larger storms may safely overflow or bypass the filters. Flow splitters, multi-stage chambers, or other devices may be used. A flow splitter may be necessary to allow only a portion of the runoff to enter the filter. This would create an “off-line” filter, where the volume and velocity of runoff entering the filter is controlled. If the filter is “on-line”, excess flow should be designed to bypass the filter and continue to another water quality BMP.

2. **Entering velocity must be controlled**. A level spreader may be used to spread flow evenly across the filter surface during all storms without eroding the filter material. Level spreaders for this purpose should use a concrete lip or other non soil material to avoid clogging as a result of failure of the level spreader lip. Parking lots may be designed to sheet flow into filters. Small rip-rap or landscaped riverstone edges may be used to reduce velocity and distribute flows more evenly.

3. Contributing areas must be **stabilized** with vegetation or other permanent soil cover before runoff enters filters. Permanent filters should not be installed until the site is stabilized. Excessive sediment generated during construction can clog the filter and prevent or reduce the anticipated post-construction water quality benefits.

4. **Pretreatment** may be necessary in areas with especially high levels of debris, large settled particulates, etc. Pretreatment may include a forebay, oil/grit separators, vegetated filter strips, or grass swales. These measures will settle out the large particles and reduce velocity of the runoff before it enters the filter. Regular maintenance of the pretreatment is critical to avoid wastes being flushed though and causing the filter to fail. Forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.

5. There should be sufficient space (head) between the top of the filtering bed and the overflow of the filter to allow for the maximum head designed to be stored before filtration.

6. The **filter media** may be a variety of materials (sand, peat, GAC, leaf compost, pea gravel, etc) and in most cases should have a minimum depth of 18 inches and a maximum depth of 30 inches, although variations on these guidelines are acceptable if justified by the designer. Coarser materials allow for greater hydraulic conductivity, but finer media filter particles of a smaller size.

   Sand has been found to provide a good balance between these two criteria, but different types of media remove different pollutants. While sand is a reliable material to remove total suspended solids, peat removes slightly more total phosphorous, copper, cadmium, and nickel than sand (Debusk and Langston, 1997).

   The filter media should have a minimum hydraulic conductivity (k) as follows:

   - Sand 3.5 feet/day
   - Peat 2.5 feet/day
   - Leaf compost 8.7 feet/day

   Depending on the characteristics of the stormwater runoff, a combination of filter materials will provide the best quality results. In addition to determining the degree of filtration, media particle size determines the travel time in the filter and plays a role in meeting release rate requirements.

   Sand filtration enhanced with steel wool, calcareous sand, or limestone provides a practical and cost-effective method for reducing levels of dissolved phosphorus (Erickson et al, Journal of Environmental Engineering, 2007). Sand enhanced with steel wool fabric proved especially effective, removing between 25 percent and 99 percent of dissolved phosphorus and enhancing the quantity and duration of phosphorous retention as compared to sand alone. Sand enhanced with calcareous sand or limestone exhibited signs of clogging in the Erickson et al study. The study also found that enhancing sand filtration with steel wool fabric would modestly increase construction costs by approximately three to five percent. As with other sand filtration systems, steel-enhanced sand filters should be sized and installed according to local guidelines, with consideration given to proper pretreatment for influent solids, as necessary.

7. A **gravel layer** at least six inches deep is recommended beneath the filter media.

8. **Underdrain piping** should be double-walled with four-inch minimum (diameter) perforated pipes, with a lateral spacing of no more than 10 feet. A collector pipe can be used, (running perpendicular to laterals) with a slope of one percent. All underground pipes should have clean-outs accessible from the surface. Underdrain design must minimize the chance of clogging by including a pea gravel filter of at least three inches of gravel under the pipe and six inches above the pipe.

9. Infiltration filters should be underlain by a layer of permeable nonwoven geotextile.

10. A total **drawdown time** of no more than 72 hours is recommended for constructed filters, though the surface should drawdown between 24 and 48 hours. The drawdown time can be estimated using the filter surface area and the saturated vertical infiltration rate of the filter media. If the storage does not drawdown in the time allowed, adjust the pretreatment depth, the filter media depth, and the surface area. Adjust the design until the volume (if applicable) and drainage time constraints are met.

11. The filter **surface area** may be estimated initially using Darcy's Law, assuming the soil media is saturated:

$$A = V * d_f / [k * (h_f + d_f) * t_f]$$

A = Surface area of filter (ft^2)
V = Water volume (ft^3)
d_f = Depth of filter media (min 1.5 ft; max 2.5 ft)
t_f = Drawdown time (days), not to exceed 3 days
h_f = Head (average head in feet; typically ½ of the maximum head on the filter media, which is typically ≤ to 6 ft)
k = Hydraulic conductivity (ft/day)

12. For vegetated filters, a layer of nonwoven geotextile between non-organic filter media and planting media is recommended.

13. Filters, especially those that are subsurface, must be **designed with sufficient maintenance access** (clean-outs, room for surface cleaning, entry space, etc.). Filters that are visible and simple in design are more likely to be maintained correctly. For underground vault heights greater than four feet, ladder access is necessary.

14. In areas where infiltration is infeasible due to a hot spot or unstable fill that threatens an existing structure, specify an **impervious liner**.

Stormwater Functions and Calculations

Volume reduction

If a filter is designed to include infiltration, the infiltration BMP should be followed. There is minimal, if any, volume reduction for filters that are not designed to infiltrate.

Peak rate mitigation

Constructed filters generally provide little, if any, peak rate reduction. However, if the filter is designed to infiltrate, then medium to high levels of peak rate attenuation can be expected.

Water quality improvement

Constructed filters are considered an excellent stormwater treatment practice with the primary pollutant removal mechanism being filtration and settling. Less significant pollutant removal may result from evaporation, transpiration, biological and microbiological uptake, and soil adsorption.

Sand filters have been shown to have a high removal efficiency of Total Suspended Solids (TSS), and medium removal efficiencies for Total Nitrogen (TN) and Total Phosphorus (TP). Organic filter media also perform very well for TSS and standard for TP, but perform relatively poorly for TN (See **Table 1**).

For filters that are also designed to infiltrate, see the water quality summary in the subsurface infiltration bed section, or in the infiltration BMP. For manufactured, proprietary systems, see the manufacturer's information. Also see the Post-Construction Stormwater Quality Management Chapter of Technical Standards, which addresses pollutant removal effectiveness of this BMP.

Construction Guidelines

1. Follow the recommended materials for constructed filters listed in Recommended Materials Appendix.

2. Structures such as inlet boxes, reinforced concrete boxes, etc. should be installed in accordance with the guidance of the manufacturers or design engineer.

3. Excavated or structural filters that infiltrate should be excavated in such a manner as to avoid compaction of the subbase. Structures may be set on a layer of clean, lightly compacted gravel (such as AASHTO #57).

4. Place underlying gravel/stone in maximum six-inch lifts and lightly compact. Place underdrain pipes in gravel during placement.

5. Wrap and secure gravel/stone with nonwoven geotextile to prevent clogging with sediments.

6. Lay filtering material. Do not compact.

7. Saturate filter media with water and allow media to drain to properly settle and distribute.

Maintenance

Filters require a regular inspection and maintenance program to maintain the integrity of filtering systems and pollutant removal mechanisms. Studies have shown that filters are very effective upon installation, but quickly decrease in efficiency as sediment accumulates in the filter. Odor is also a concern for filters that are not maintained. Inspection of the filter is recommended at least four times a year.

When a filter has accumulated sediment in its pore space, its hydraulic conductivity is reduced, along with its ability to removal pollutants. Inspection and maintenance are essential for continued performance of a filter. Based upon inspection, some or all portions of the filter media may require replacement.

During the inspection the following conditions should be considered:

- **Standing water** – any water left in a surface filter after the design drain down time indicates the filter is not functioning according to design criteria.
- **Film or discoloration** of any surface filter material – this indicates organics or debris have clogged the filter surface.
- Remove trash and debris as necessary
- Scrape silt with rakes, if collected on top of the filter
- Till and aerate filter area
- Replenish filtering medium if scraping/removal has reduced depth of filtering media
- Repair leaks from the sedimentation chamber or deterioration of structural components
- Clean out accumulated sediment from filter bed chamber and/or sedimentation chamber
- Clean out accumulated sediment from underdrains

Studies	No. of studies	TSS % Removal		TN % Removal		TP % Removal	
		Range	Median	Range	Median	Range	Median
U.S.*	18	80 - 92	86	30-47	32	41-66	59
International**	38		75		44		45
Organic media*	N/A	85-100		poor		50-85	

Table 1 Pollutant Removal efficiencies for sand filters
**The Center for Watershed Protection, in its National Pollutant Removal Performance Database – Version 3 (September 2007)*
***The International Stormwater Best Management Practices (BMP) Database, October 2007*

In areas where the potential exists for the discharge and accumulation of toxic pollutants (such as metals), filter media removed from filters must be handled and disposed of in accordance with all state and federal regulations.

Winter Considerations

Indiana's winter temperatures can go below freezing for a few months out of every year and surface filtration does not work as well in the winter. Peat and compost may hold water freeze, and become relatively impervious on the surface. Design options that allow directly for subsurface discharge into the filter media during cold weather may overcome this condition. Otherwise, the reduced performance when the filter media may be temporarily frozen should be considered.

There are various filtration options available for treating snowmelt runoff. In some cases, installations are built below the frost line (trenches, subgrade proprietary chambers) and do not need further adaptation for the cold. However, some special consideration is highly recommended for surface systems.

The main problem with filtration in cold weather is the ice that forms both over the top of the facility and within the soil. To avoid these problems to the extent possible, it is recommended that the facility be actively managed to keep it dry before it freezes in the late fall. Additional modifications, such as increasing the size of underdrains to eight inches, increasing the slope of the underdrains to one percent, and increasing the thickness of the gravel layer to at least 12 inches can prevent freezing and are recommended by EPA.

Proprietary, subsurface filter systems provide an alternative to standard surface-based systems. Essentially, these systems provide an insulated (i.e., subsurface) location for pre-treated snowmelt to be filtered. The insulating value of these systems adds to their appeal as land conserving alternatives to ponds and surface infiltration basins.

Cost

Filter costs vary according to the filtering media (sand, peat, compost), land clearing, excavation, grading, inlet and outlet structures, perforated pipes, encasing structure (if used), and maintenance cost. Underground structures may contribute significantly to the cost of a filter. In general, filters are one of the more costly and maintenance-intensive BMPs.

Underground sand filters are generally considered to be a high-cost option for water quality management. In 1994, the construction cost was estimated between $10,000 to $14,000 per impervious acre served, excluding real estate, design, and contingency costs (Schueler, 1994).

In ultra-urban areas where land costs are high, however, underground sand filters can represent significant cost savings in reduced land consumption. For small ultra-urban areas with no land available, underground sand filters may be the only practical option for stormwater quality treatment as they can be placed under roads or parking lots.

In recent years, various manufacturers have made available prefabricated units that include precast vaults and inlets delivered to the site either partially or fully assembled. These units have generally resulted in decreased construction costs. Typical significant cost variables include the location of subsurface utilities, type of lids and doors, customized casting of weirs, sections, or holes, and depth of the vault.

The surface sand filter design is a moderately expensive water quality option to employ (Claytor and Schueler, 1996). However, the cost of installation is strongly correlated with the nature of the construction employed. If the filter is installed within an ultra-urban setting, it is likely that relatively expensive concrete walls will be used to create the various chambers. This type of installation will be significantly more expensive than an earthen-walled design, where relatively inexpensive excavation and compaction construction techniques lower the installation cost. However, earthen-wall designs require a greater land area commitment, which can offset the reduction in construction costs.

The construction cost of surface sand filters is also related to economies of scale: the cost per impervious acre served typically decreases with an increase in the service area. In 1994, the construction costs for surface sand or organic media filters were $16,000 per impervious acre for facilities serving less than two acres (Schueler, 1994). Once again, these construction cost estimates exclude real estate, design, and contingency costs.

Designer/Reviewer Checklist for Constructed Filters

Type of constructed filter(s) proposed: ____

Type of filter media proposed: ____

ITEM	Page No.	YES	NO	N/A	NOTES
Adequate depth of filter media? ➢ *Minimum Depth: 18 inches; maximum depth: 36 inches*	1				
Acceptable drawdown time (72 hour max.)?	1,6				
Pretreatment provided?	2,5				
Adequate hydraulic head available for filter to operate?	1,5				
Flow bypass and/or overflow provided?	1,4-5				
Permeability of filter media acceptable? ➢ *Minimum hydraulic conductivity (k); sand = 3.5 ft/day; peat = 2.5 ft/day; compost = 8.7 ft/day*	5				
Underdrain provided for non infiltration systems?	1				
Appropriate placement of nonwoven filter fabric?	2-3,6				
Gravel layer provided beneath filter media? ➢ *Minimum depth: 6 inches*	6				
Non-erosive inflow condition?	5				
Adequate surface area provided?	6				
Construction timing places installation after site stabilization?	5				
Erosion control provided during construction?	--				
Cleanouts included?	6				
Maintenance accounted for and plan provided?	7				

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

DETENTION BASINS - CONSTRUCTED WETLAND

A constructed wetland is a type of detention basin that is developed as shallow marsh system planted with emergent vegetation designed to treat stormwater runoff.

Figure 1 Photo Courtesy of USDA NRCS

Variations

- Shallow Wetlands
- Extended Detention Shallow Wetlands
- Pocket Wetlands
- Pond/Wetland

Key Design Features

- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Natural high groundwater table required
- Relatively impermeable soils or impermeable liner
- Forebay for sediment collection and removal
- Dewatering mechanism required
- Stabilized emergency overflow and energy dissipation at all outlets

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	No
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Stormwater Quality Functions
Varies by type as follows:

Type	TSS	TP	TN	Temperature
Constructed Wetland	High	Medium	Medium	Low/Medium

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Const. Wetland	Can be below WT	C or D*	Low	Yes w/ consider-ations	50	Good peak rate & water quality performance, wide applicability, potential aesthetic/ habitat value	Limited volume/GW recharge benefits, high total cost, potentially thermal impact

**C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.*

Additional Considerations

Cost

- High – Cost must include excavation of basin and enhanced vegetation.
- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Constructed Wetland	Low/Med

Winter Performance

- Med/High

Description and Function

Constructed wetlands are shallow marsh systems planted with emergent vegetation designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, constructed wetlands can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits. Constructed wetlands use a relatively large amount of space and may require an adequate source of inflow if a permanent water surface is maintained. (Not all constructed wetlands maintain a water surface year round).

Applications

Constructed wetlands can be used in a wide variety of applications when the necessary space is available. Their use is limited in ultra urban areas and some redevelopment projects simply due to a lack of available space (in these cases underground and/or special detention may be used).

Variations

Constructed wetlands can be designed as either online (within the stormwater system) or offline facilities. They can be used effectively in series with other flow/ sediment reducing BMPs that reduce the sediment load and equalize incoming flows to the constructed wetland. They are a good option for retrofitting existing detention basins and are often organized into the following four groups:

- **Shallow wetlands** are large surface area constructed wetlands that primarily accomplish water quality improvement through displacement of the permanent pool.

- **Extended detention shallow wetlands** are similar to shallow wetlands but use extended detention as another mechanism for water quality and peak rate control.

- **Pocket wetlands** are smaller constructed wetlands that serve drainage areas between approximately 5 and 10 acres and are constructed near the water table.

- **Pond/wetland** systems are a combination of wet ponds and constructed wetlands.

Although discussion of constructed wetlands in this BMP focuses on surface flow as described above, subsurface flow constructed wetlands can also be used to treat stormwater runoff.

While typically used for wastewater treatment, subsurface flow constructed wetlands for stormwater can offer some advantages over surface flow wetlands, such as improved reduction of total suspended solids and biological oxygen demand. They also can reduce the risk of disease vectors (especially mosquitoes) and safety risks associated with open water. However, nitrogen removal may be deficient (Campbell and Ogden, 1999) if most of the incoming nitrogen is in the form of ammonia. Subsurface flow wetlands are poor converters of ammonia to nitrate (nitrification) but are excellent converters of nitrate to nitrogen gas (denitrification). Perhaps the biggest concern regarding subsurface constructed wetlands is their relatively high cost. They can be two to three times more expensive to construct than surface flow constructed wetlands.

Design Considerations

Hydrology

- Constructed wetlands should be designed to mitigate peak runoff rates for the one-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the local Stormwater Ordinance. Typically, the NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.
- Constructed wetlands must be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. Hydrologic calculations (e.g., a water balance) must be performed to verify this. Shallow marsh areas can become dry at the surface but not for greater than one month, even in the most severe drought. A permanent water surface in the deeper areas of the constructed wetland should be maintained during all but the driest periods. The average target pool depth to maintain emergent wetland vegetation is six to 12 inches. Maximum water depths of three to four feet should not be exceeded for more than 12 hours at a time, for more than a few days out of the year. The deeper the water and the longer it sits, the greater the chances that a wetland vegetation monoculture, such as cattails, will develop. A relatively stable normal water surface elevation reduces the stress on wetland vegetation. A constructed wetland must have a drainage area of at least 10 acres (five acres for "pocket" wetlands) or some means of sustaining constant inflow. Even with a large drainage area, a consaarea, a constant source of inflow can improve the biological health and effectiveness of a constructed wetland. Indiana's precipitation is generally well distributed throughout the year and is therefore suited for constructed wetlands.

Storage volume, depth, and duration

- Constructed wetlands should be designed to treat the runoff volume produced by the water quality design storm unless additional upstream BMPs are provided.
- If high water table conditions are anticipated, then the design of a constructed wetland should be considered.
- Ponding depths should not exceed 3 – 4 feet for more than 12 hours.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin. In order to achieve an 80 percent total suspended solids removal rate, a 36-hour detention time is required within an extended detention basin, with no more than 40% of the maximum stored volume released within the first 12 hours.

Basin sizing and configuration

- Constructed wetlands should be shaped to maximize the hydraulic length of the stormwater flow pathway. A minimum length-to width ratio of 3:1 is recommended to maximize sedimentation. If the length-to-width ratio is lower, the flow pathway should be maximized. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.
- Irregularly shaped basins are acceptable and may even be encouraged to improve site aesthetics.
- Distances of flow paths from inflow points to outlets should be maximized.
- If site conditions inhibit construction of a long, narrow basin, baffles consisting of

earthen berms or other materials can be incorporated into the pond design to lengthen the stormwater flow path.
- Constructed wetlands must have one or more sediment forebays or equivalent upstream pretreatment to trap coarse sediment, prevent short circuiting and facilitate maintenance (i.e., sediment removal). The forebay should consist of a separate cell, formed by a structural barrier. The forebay will require periodic sediment removal.
- Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least nine feet wide, having a maximum slope of 15 percent, and be stabilized for vehicles.
- An emergency outlet or spillway capable of conveying the spillway design flood (SDF) must be included in the design. The SDF is usually equal to the 1.25 times the 100-year design flood.
- Constructed wetlands should be designed so that the 10-year water surface elevation does not exceed the normal water surface elevation by more than three feet. Slopes in and around constructed wetlands should be 4:1 to 5:1 (horizontal:vertical) whenever possible.
- All areas that are deeper than four feet should have two safety benches, each four to six feet wide. One should be situated about one to 1.5 feet above the normal water elevation and the other 2 to 2.5 feet below the water surface.

Embankments

- Vegetated embankments less than or equal to three feet in height are recommended. Embankments should have side slopes no steeper than 3:1 (horizontal to vertical).
- The constructed wetland should have a minimum freeboard of one foot above the SDF elevation to the top of the berm.
- Woody vegetation is generally discouraged in the embankment area because of the risk of compromising the integrity of the embankment.
- Embankments should incorporate measures, such as buried chain link fencing, to prevent or discourage damage caused by tunneling wildlife (e.g., muskrat).

Constructed wetland location

- Constructed wetlands should be located down gradient of disturbed or developed areas on the site. The constructed wetland should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Constructed wetlands should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a basin.
- Constructed wetlands should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a basin.
- Constructed wetlands should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Constructed wetlands should not be constructed in areas with high quality and/or well draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Outlet design

- The low-flow orifice should typically be no smaller than 4 inches in diameter. However, the orifice diameter may be reduced to two inches if adequate protection from clogging is provided.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash rack or other mechanism.
- Online facilities should have an emergency spillway that can safely pass 1.25 times the 100-year storm with one foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.
- Outlet control devices should be in open water areas, four to six feet deep, comprising about five percent of the total surface area to prevent clogging and allow the wetland to be drained for maintenance. Outlet devices are

generally multistage structures with pipes, orifices, or weirs for flow control. All outflows should be conveyed downstream in a safe and stable manner.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.

Sediment forebay

- Forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.
- Forebays must be incorporated into the basin design. Forebays should be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin, and minimize erosion by inflow.
- Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays should adhere to the following criteria:
  - A minimum length of 10 feet.
  - Storage should be provided to trap sediment over from storms with return periods between 1and 10 years.
  - Forebays should be physically separated from the rest of the pond by a berm, gabion wall, etc.
  - Flows exiting the forebay must be non-erosive to the newly constructed basin.
  - Forebays should be installed with permanent vertical markers that indicate sediment depth.
  - Storage volume of 10 to 15 percent of the total permanent pool volume and is four to six feet deep.
  - All major inflow points to dry detention basins should include sediment forebays sized for 10 percent of the water quality volume.

Vegetation and soils protection

- Underlying soils must be identified and tested. Generally, hydrologic soil groups “C” and “D” are suitable without modification; “A” and “B” soils may require a clay or synthetic liner. Soil permeability must be tested in the proposed constructed wetland location to ensure that excessive infiltration will not cause it to dry out. Field results for permeability should be used in the water balance calculations to confirm suitability. If necessary, constructed wetlands should have highly compacted subsoil or an impermeable liner to minimize infiltration.
- Organic soils should be used for constructed wetlands. Organic soils can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species. Care must be taken to ensure that soils used are free of invasive or nuisance plant seed.
- About half of the emergent vegetation zone should be high marsh (up to six inches deep) and half should be low marsh (6 to 18 inches deep). Varying depths throughout the constructed wetland can improve plant diversity and health.
- The open water zone (approx.imately 35 to 40 percent of the total surface area) should be between 18 inches and six feet deep. Allowing a limited five-foot deep area can prevent short-circuiting by encouraging mixing, enhance aeration of water, prevent resuspension, minimize thermal impacts, and limit mosquito growth. Alternating areas of emergent vegetation zone (up to 18 inches deep) and open water zone can also minimize short-circuiting and hinder mosquito propagation.

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Excavation

- The area to be used for the constructed wetland should be excavated to the required depth below the desired bottom elevation to

accommodate any required impermeable liner, organic matter, and/or planting soil.
- The compaction of the subgrade and/or the installation of any impermeable liners will follow immediately.

Subsoil preparation

- Subsoil should be free from hard clods, stiff clay, hardpan, ashes, slag, construction debris, petroleum hydrocarbons, or other undesirable material. Subsoil must not be delivered in a frozen or muddy state.
- Scarify the subsoil to a depth of 8 to 10 inches with a disk, rototiller, or similar equipment.
- Roll the subsoil under optimum moisture conditions to a dense seal layer with four to six passes of a sheepsfoot roller or equivalent. The compacted seal layer should be at least eight inches thick.

Impermeable liner

- If necessary, install impermeable liner in accordance with manufacturer's guidelines.
- Place a minimum 12 inches of subsoil on top of impermeable liner in addition to planting soil.

Earth fill material & placement

- The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than six inches, or other objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.
- Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum eight-inch lifts. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.
- Control movement of the hauling and spreading equipment over the site.

Embankment core

- The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1:1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.
- Construction of the berm should follow specifications by the project's geotechnical engineer.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driven equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

Corrugated metal pipe – All of the following criteria should apply for corrugated metal pipe:
- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.

- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Reinforced concrete pipe - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Plastic pipe

- Materials – PVC pipe should be PVC-1120 or PVC-1220, conforming to ASTM standards. Corrugated High Density Polyethylene (HDPE) pipe, couplings, and fittings should meet AASHTO specifications.
- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Drainage diaphragms – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Planting soil (topsoil)

- See local specifications for general planting soil requirements.
- Use a minimum of 12 inches of topsoil in the emergent vegetation zone (less than 18" inches deep) of the pond. If natural topsoil from the site is to be used it must have at least eight percent organic carbon content (by weight) in the A-horizon for sandy soils, and 12 percent for other soil types.
- If planting soil is imported, it should be made up of equivalent proportions of organic and mineral materials. All soils used should be free of invasive or nuisance seeds.
- Lime should not be added to planting soil unless absolutely necessary, as it may encourage the propagation of invasive species.
- The final elevations and hydrology of the vegetative zones should be evaluated prior to planting to determine if grading or planting changes are required.

Vegetation

- See Recommended Plant List for BMPs Appendix for plant lists for constructed wetlands. Substitutions of specified plants should be subject to prior approval of the designer. Planting locations should be based on the planting plan and directed in the field by a qualified wetland ecologist. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

- All wetland plant stock should exhibit live buds or shoots. All plant stock should be turgid, firm, and resilient. Internodes of rhizomes may be flexible and not necessarily rigid. Soft or mushy stock should be rejected. The stock should be free of deleterious insect infestation, disease, and defects such as knots, sun-scald, injuries, abrasions, or disfigurement that could adversely affect the survival or performance of the plants.
- All stock should be free from invasive or nuisance plants or seeds.
- During all phases of the work, including transport and onsite handling, the plant materials should be carefully handled and packed to prevent injuries and desiccation. During transit and onsite handling, the plant material should be kept from freezing and be covered, moist, cool, out of the weather, and out of the wind and sun. Plants should be watered to maintain moist soil and/or plant conditions until accepted.
- Plants not meeting these specifications or damaged during handling, loading, and unloading will be rejected.

Outlet control structure

- Outlet control structures should be constructed of non-corrodible material.
- Outlets should be resistant to clogging by debris, sediment, floatables, plant material, or ice.
- Materials should comply with applicable specifications (INDOT or AASHTO, latest edition).
- For maximum flexibility with wetland water levels (if actual depths are uncertain) adjustable water level control structures are recommended (see EPA, 2000 in reference section for design concepts).

Stormwater Functions and Calculations

Volume reduction

Although not typically considered a volume-reducing BMP, constructed wetlands can achieve some volume reduction through infiltration and evapotranspiration, especially during small storms and high temperature periods. The volume stored between the predicted water level (from the water balance calculations) and the lowest outlet elevation will be removed from the storm that occurs under those conditions.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled in detention facilities through the transient storage above any permanent water surface. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

Constructed wetlands rely on physical, biological, and chemical processes to remove pollutants from influent stormwater runoff. The primary treatment mechanism is settling by gravity of particulates and their associated pollutants, while stormwater is retained in the pond. Another mechanism for the removal of pollutants, especially nutrients, is uptake by algae and aquatic vegetation. Typical pollutant removal efficiencies are provided in the Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

The longer the runoff remains in a constructed wetland, the more settling (and associated pollutant removal) and other treatment can occur. After the particulates reach the bottom, the permanent pool protects them from resuspension when additional runoff enters.

Construction Guidelines

The following guidelines pertain to constructed wetlands:

- Install all temporary erosion and sedimentation controls.
- Separate pond area from contributing drainage area.
- All channels/pipes conveying flows to the pond must be routed away from the pond area until it is completed and stabilized.
- Prior to construction of the pond, the area immediately adjacent to the pond must be stabilized in accordance with the erosion and sediment control methods discussed in the Erosion and Sediment Control Requirements Chapter of the Technical Standards and the latest requirements of IDEM's Soil Erosion and Sedimentation Control (Rule 5) Program.
- Prepare site for excavation and/or embankment construction.
- All existing vegetation should remain, if feasible, and only be removed if necessary for construction.
- Care should be taken to prevent compaction of the basin bottom.
- If excavation is required, clear the area of all vegetation. Remove all tree roots, rocks, and boulders only in the excavation area.
    - Excavate bottom of basin to desired elevation (if necessary).
- Install surrounding embankments and inlet and outlet control structures.
- Grade and prepare subsoil in bottom of basin. Compact bottom of basin in constructed wetlands.
    - Apply and grade planting soil. Matching design grades is crucial especially in constructed wetlands because aquatic plants can be very sensitive to depth.
    - Apply geo-textiles and other erosion-control measures.
- Seed, plant, and mulch according to landscaping plan.
- Install any safety or anti-grazing measures, if necessary.
- Follow required maintenance and monitoring guidelines.

Maintenance

Constructed wetlands must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.
- Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every 3 to 10 years. Sediment removal should be conducted when the basin is completely dry.
- Constructed wetlands should be drained prior to sediment removal. Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots such as fueling stations or areas with high pollutant concentrations should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.
- The wetland drain should be inspected and tested four times per year.
- The embankment should be inspected for evidence of tunneling or burrowing wildlife at least twice during the growing season. If damage is found, the damage should be repaired and the animals removed.
- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus must be removed from the basin. Embankment should be mowed 1–2 times per year to prevent the establishment of woody vegetation.

- Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation.
- Vegetated areas should be inspected annually for unwanted growth of invasive species.
- Vegetative cover should be maintained at a minimum of 85 percent.

Winter Considerations

One of the biggest problems associated with proper constructed wetland operation during cold weather is the freezing and clogging of inlet and outlet pipes. To avoid these problems, the Center for Watershed Protection (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should typically not be submerged, since this can result in freezing and upstream damage or flooding.
- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes "turn the corner" are helpful.
- Incorporate lower winter operating levels as part of the design to introduce available storage for melt events.
- Increase the slope of inlet pipes to a minimum of one percent to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.
- If perforated riser pipes are used, the minimum opening diameter should be ½-inch. In addition, the pipe should have a minimum 8-inch diameter.
- When a standard weir is used, the minimum slot width should be 3 inches, especially when the slot is tall.
- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.
- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least 6 inches below the typical ice layer.
- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water-quality events. This practice both avoids stream warming and serves as a non-freezing outlet.
- Trash racks should be installed at a shallow angle to prevent ice formation. Constructed wetland performance can be decreased in spring months when large volumes of runoff occur in a relatively short time carrying the accumulated pollutant load from the winter months. Since constructed wetlands are relatively shallow, freezing of the shallow pool can occur.

Cost

The cost of constructed wetlands varies greatly depending on the configuration, location, site specific conditions, etc. Typical construction costs in 2004 dollars range from approximately $30,000 to $65,000 per acre (USEPA Wetlands Fact Sheet, 1999). Costs are generally most dependent on the amount of earthwork and planting. Annual maintenance costs have been reported to be approximately two to five percent of the capital costs (USEPA, 2000).

Designer/Reviewer Checklist for Constructed Wetlands

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for groundwater recharge and/or water quality?	1,3				
Adequate drainage area/water supply/groundwater table to maintain permanent water surface? ➢ *Min. drainage area:* ***10 acres, 5 acres for pocket wetland*** ➢ *Max. drainage area:* ***50 acres***	2-4				
Relatively impermeable soils and/or soil modification?	6				
Hydrologic calculations (e.g., water balance) performed?	3,4				
Stable inflow points provided?	6				
Forebay and/or pretreatment provided for sediment removal? ➢ *Min. width of permanent access:* ***9 ft*** ➢ *Max. slope:* ***15%***	4-6				
Adequate length to width ratio?	4				
Appropriate and varying water depths for diverse vegetation? ➢ *Max. water depth:* ***3-4 feet, no longer than 12 hours for more than a few days annually***	4,6				
Sudden water level fluctuations minimized to reduce stress on vegetation?	4				
Acceptable side slopes?	5				
Safety benches provided?	5				
Properly designed outlet structure?	4,5				
Adjustable permanent pool and dewatering mechanism provided?	--				
Trash rack provided to prevent clogging?	5				
Stable emergency overflow and outflow points?	5				
Adequate soils for plantings?	6,7				
Appropriate native plants selected in and around wetland?	9				
25-foot buffer provided?	--				
Erosion and sedimentation control considered?	--				
Maintenance accounted for and plan provided? ➢ *Min. vegetative cover to be maintained:* ***85%***	10,11				

➢ *Denotes Minimum Design Consideration*

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BMP Fact Sheet

DETENTION BASINS - DRY POND

Also called Dry-bottom Detention Ponds, Dry Ponds are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding.

Figure 1 Photograph Courtesy of US Environmental Protection Agency

Key Design Features

- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Relatively impermeable soils or impermeable liner
- Forebay for sediment collection and removal
- Stabilized emergency overflow and energy dissipation at all outlets

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	No
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Stormwater Quality Functions

Type	TSS	TP	TN	Temperature
Dry Pond	Medium	Medium	Low	Low

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Dry Pond	Above	N/A	Low/ Med	Yes w/ considerations	50	Good peak rate performance, wide applicability, can be used as temporary sediment basin	Low volume/GW recharge and water quality benefits, must be combined with other BMPs, high total cost

**C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.*

Additional Considerations

Cost

- High – Cost for above ground basins must include excavation of basin, construction of berm, and installation of storm sewer conveyance system, including pipes and structures.
- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Dry Pond	High/Low - Year round maintenance for vegetation; one time per year sediment removal

Winter Performance

- Med/High

Description and Function

Dry ponds are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding. They are constructed either by impounding a natural depression or excavating existing soil, and are intended to enhance the settlement process in order to maximize water quality benefits, while achieving reduced runoff volume.

Applications

Dry ponds can be used in a wide variety of applications when the necessary space is available. Their uses are limited in ultra urban areas and some redevelopment projects simply due to a lack of available space (in these cases underground and/or special detention may be used).

Design Considerations

Hydrology

- Dry ponds should be designed to mitigate peak runoff rates for the 1-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the Stormwater Ordinance. Typically, the local NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.

Storage volume, depth, and duration

- Dry ponds should be designed to treat the runoff volume produced by the water quality design storm unless additional upstream BMPs are provided.
- The lowest elevation within a dry detention basin should be at least two feet above the seasonal high water table. If high water table conditions are anticipated, then the design of a wet pond, constructed wetland, or bioretention facility should be considered.
- The maximum water depth of the basin should not exceed 4 feet.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin. In order to

achieve an 80 percent total suspended solids removal rate, a 36-hour detention time is required within an extended detention basin, with no more than 40% of the maximum stored volume released within the first 12 hours.

- The low flow orifice should be sized and positioned to detain the calculated water quality runoff volume for at least 24 hours, but no more than 36 hours. The low flow orifice may be allowed as small as 4 inches in diameter if adequate protection from clogging is provided.

Basin sizing and configuration

- Dry ponds should be shaped to maximize the hydraulic length of the stormwater flow pathway. A minimum length-to width ratio of 3:1 is recommended to maximize sedimentation. If the length-to-width ratio is lower, the flow pathway should be maximized. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.
- Irregularly shaped basins are acceptable and may even be encouraged to improve site aesthetics.
- Distances of flow paths from inflow points to outlets should be maximized.
- If site conditions inhibit construction of a long, narrow basin, baffles consisting of earthen berms or other materials can be incorporated into the pond design to lengthen the stormwater flow path.
- Basins must have one or more sediment forebays or equivalent upstream pretreatment to trap coarse sediment, prevent short circuiting and facilitate maintenance (i.e., sediment removal). The forebay should consist of a separate cell, formed by a structural barrier. The forebay will require periodic sediment removal.
- Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least nine feet wide, having a maximum slope of 15 percent, and be stabilized for vehicles.
- An emergency outlet or spillway capable of conveying the spillway design flood (SDF) must be included in the design. The SDF is usually equal to the 1.25 times the 100-year design flood.

Embankments

- Vegetated embankments less than or equal to three feet in height are recommended. Embankments should have side slopes no steeper than 3:1 (horizontal to vertical).
- The basin should have a minimum freeboard of one foot above the SDF elevation to the top of the berm.
- Woody vegetation is generally discouraged in the embankment area because of the risk of compromising the integrity of the embankment.
- Embankments should incorporate measures, such as buried chain link fencing, to prevent or discourage damage from tunneling wildlife (e.g., muskrat).

Figure 2 Dry Pond: Photo courtesy of Fairfax County VA Department of Public Works and Environmental Services.

Dry pond location

- Dry ponds should be located down gradient of disturbed or developed areas on the site. The pond should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Dry ponds should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a pond.
- Dry ponds should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a pond.

- Dry ponds should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Dry ponds should not be constructed in areas with high quality and/or well draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Additional design considerations for extended detention basins (Figure 3)

- Dry detention basins should not be constructed within jurisdictional waters, including wetlands, or their regulated buffers.

Outlet design

- The low-flow orifice should typically be no smaller than 4 inches in diameter. However, the orifice diameter may be reduced to two inches if adequate protection from clogging is provided.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash rack or other mechanism.
- Online facilities should have an emergency spillway that can safely pass the 1.25 times the 100-year storm with one foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.
- When designed to meet discharge criteria for a range of storms, basins should incorporate a multistage outlet structure. Three elements are typically included in this design:

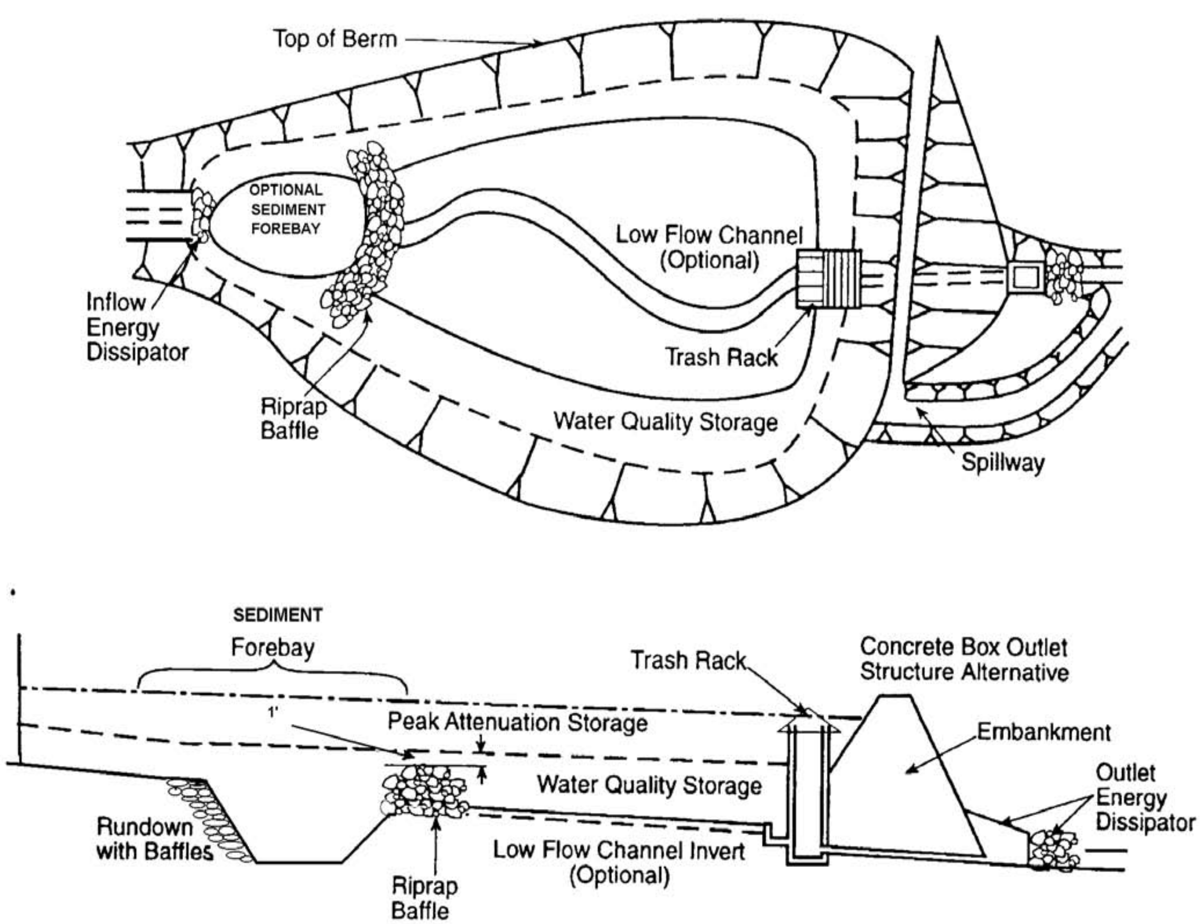

Figure 3 Extended Detention Basin
Source: New Jersey BMP Manual

- A low-flow outlet that controls the extended detention and functions to slowly release the water quality or channel protection design storm.
- A primary outlet that functions to attenuate the peak of larger design storms.
- An emergency overflow outlet/ spillway. The emergency spillway should be at the top of the berm.

- The primary outlet structure should incorporate weirs, orifices, pipes, or a combination of these to control runoff peak rates for multiple design storms. Water quality storage should be provided below the invert of the primary outlet. When routing basins, the low-flow outlet should be included in the depth-discharge relationship.
- Energy dissipaters should be placed at the end of the primary outlet to prevent erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel. Where feasible, a multiple orifice outlet system is preferred to a single pipe.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.

Sediment forebay

- Must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.
- Forebays must be incorporated into the basin design. Forebays should be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin, and minimize erosion by inflow.
- Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays should adhere to the following criteria:
  - A minimum length of 10 feet.
  - Storage should be provided to trap sediment over from storms with return periods between 1 and 10 years.
  - Forebays should be physically separated from the rest of the pond by a berm, gabion wall, etc.
  - Flows exiting the forebay must be non-erosive to the newly constructed basin.
  - Forebays should be installed with permanent vertical markers that indicate sediment depth.
  - Storage volume of 10 to 15 percent of the total permanent pool volume and is four to six feet deep.
  - All major inflow points to dry detention basins should include sediment forebays sized for 10 percent of the water quality volume.

Vegetation and soils protection

- Care should be taken to prevent compaction of soils in the bottom of the extended detention basin in order to promote healthy plant growth and encourage infiltration. If soils compaction is not prevented during construction, soils should be restored as discussed in the Soils Restoration BMP.
- Basin bottoms and side slopes should be vegetated with a diverse native planting mix to reduce maintenance needs, promote natural landscapes, and increase infiltration potential.
- Vegetation may include trees, woody shrubs, and meadow/wetland herbaceous plants.
- Woody vegetation is generally discouraged in the embankment.
- Meadow grasses or other deeply rooted herbaceous vegetation is recommended on the interior slope of embankments.
- Fertilizers and pesticides should not be used.

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Site preparation

All excavation areas, embankments, and structure locations should be cleared and grubbed as necessary, but trees and existing vegetation should be retained and incorporated within the dry detention basin area where possible. Trees should not be removed unless absolutely necessary.

Where feasible, trees and other native vegetation should be protected, even in areas where temporary inundation is expected. A minimum 10-foot radius around the inlet and outlet structures can be cleared to allow room for construction.

Any cleared material should be used as mulch for erosion control or soil stabilization.

Care should be taken to prevent compaction of the bottom of the reservoir. If compaction should occur, soils should be restored and amended.

Earth fill material & placement

- The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than six inches, or other objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.

- Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum eight-inch lifts. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.

- Control movement of the hauling and spreading equipment over the site.

Embankment core

- The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1:1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.

- Construction of the berm should follow specifications by the project's geotechnical engineer.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driven equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.

- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

<u>Corrugated metal pipe</u> – All of the following criteria should apply for corrugated metal pipe:

- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.
- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

<u>Reinforced concrete pipe</u> - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

<u>Plastic pipe</u>

- Materials – PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM standards. Corrugated High Density Polyethylene (HDPE) pipe, couplings, and fittings should meet AASHTO specifications.
- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

<u>Drainage diaphragms</u> – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Rock riprap

Rock riprap should meet the Construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM's Soil Erosion and Sedimentation Control Program (Rule 5).

Stabilization

All borrow areas should be graded to provide proper drainage and left in a stabilized condition. All exposed surfaces of the embankment, spillway, spoil and borrow areas, and berms should be stabilized by seeding, planting, and mulching in accordance with Construction BMP requirements contained in the Technical Standards document and the latest requirements of IDEM's Soil Erosion and Sedimentation Control Program (Rule 5).

Operation and maintenance

An operation and maintenance plan in accordance with local or state regulations must be prepared for all basins. At a minimum, include a dam and inspection checklist as part of the operation and maintenance plan and perform at least annually.

Stormwater Functions and Calculations

Volume reduction

Dry ponds do not provide an appreciable amount of volume reduction.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled through the transient storage above the bottom elevation of the dry detention facility. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

The primary treatment mechanism is settling by gravity of particulates and their associated pollutants while stormwater is retained in the pond.

Construction Guidelines

The following guidelines pertain to dry ponds:

- Install all temporary erosion and sedimentation controls.
- Separate pond area from contributing drainage area.
- All channels/pipes conveying flows to the pond must be routed away from the pond area until it is completed and stabilized.
- Prior to construction of the pond, the area immediately adjacent to the pond must be stabilized in accordance with the erosion and sediment control methods discussed in the Erosion and Sediment Control Requirements Chapter of the Technical Standards and the latest requirements of IDEM's Soil Erosion and Sedimentation Control Program (Rule 5).
- Prepare site for excavation and/or embankment construction.
- All existing vegetation should remain, if feasible, and only be removed if necessary for construction.
- Care should be taken to prevent compaction of the basin bottom.
- If excavation is required, clear the area of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area.
    - Excavate bottom of basin to desired elevation (if necessary).
- Install surrounding embankments and inlet and outlet control structures.
- Grade and prepare subsoil in bottom of basin while taking care to prevent compaction. Equipment that will apply pressure to the basin bottom of less than or equal to four pounds per square inch is recommended. Compact only the surrounding embankment areas and around inlet and outlet structures.
    - Apply and grade planting soil.
    - Apply geo-textiles and other erosion-control measures.
- Seed, plant, and mulch according to landscaping plan.
- Install any safety or anti-grazing measures, if necessary.
- Follow required maintenance and monitoring guidelines.

Maintenance

Dry ponds must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.

- Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every three to 10 years. Sediment removal should be conducted when the basin is completely dry.

- Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots, such as fueling stations or areas with high pollutant concentrations, should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.

- The pond drain should be inspected and tested four times per year.

- The embankment should be inspected for evidence of tunneling or burrowing wildlife at least twice during the growing season. If damage is found, the damage should be repaired and the animals removed.

- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus must be removed from the basin. Embankment should be mowed 1–2 times per year to prevent the establishment of woody vegetation.

- Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation.

- Vegetated areas should be inspected annually for unwanted growth of invasive species.

- Vegetative cover should be maintained at a minimum of 85 percent.

Winter Considerations

Dry ponds should be inspected and maintained during winter months. Application of sand, ash, cinders, or other anti-skid materials may cause sediment forebays to fill more quickly. Otherwise, dry ponds should function as intended in cold weather.

Cost

The construction costs associated with dry ponds can vary considerably. One study evaluated the cost of all pond systems (Brown and Schueler, 1997). Adjusting for inflation, the cost of dry extended detention ponds can be estimated with the equation:

$$C = 12.4V^{0.760}$$

Where:

C = Construction, design and permitting cost
V = Volume needed to control the 10-year storm (ft^3)

Using this equation, typical construction costs are:

$41,600 for a one acre-foot pond
$239,000 for a 10 acre-foot pond
$1,380,000 for a 100 acre-foot pond

Dry ponds using highly structural design features (riprap for erosion control, etc.) are more costly than natural basins. An installation cost savings is associated with a natural vegetated slope treatment, which is magnified by the additional environmental benefits provided. Long-term maintenance costs for processes such as mowing and fertilizing are reduced when more naturalized approaches are used, due to the ability of native vegetation to adapt to local weather conditions and a reduced need for maintenance.

Annual maintenance costs for dry ponds have been reported to be approximately three to five percent of the capital costs, though there is little data available to support this. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems may be spread over a relatively long time period.

Designer/Reviewer Checklist for Dry Extended Detention Ponds

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for groundwater recharge and/or water quality?	1				
Adequate drainage area/water supply/groundwater table to maintain permanent water surface? ➢ *Max. drainage area:* ***50 acres***	2				
Relatively impermeable soils and/or soil modification?	--				
Stable inflow points provided?	6				
Forebay and/or pretreatment provided for sediment removal? ➢ *Min. width of permanent access:* ***9 ft*** ➢ *Max. slope:* ***15%*** ➢ *Min. length of forebay:* ***10 ft***	3,6				
Adequate length to width ratio? ➢ *Min. length-to-width ratio:* ***3:1***	3				
Appropriate and varying water depths? ➢ *Max. water depth:* ***4 feet*** ➢ *Lowest elevation:* ***at least 2 feet above seasonal high water table***	3				
Acceptable side slopes? ➢ *Max. side slopes: 3:**1***	4				
Safety benches provided?	--				
Properly designed outlet structure?	5				
Dewatering mechanism provided?	--				
Trash rack provided to prevent clogging?	5				
Stable emergency overflow and outflow points?	5				
Soil compaction minimized?	6,9				
Adequate soils for plantings?	--				
Appropriate native plants selected in and around pond?	6				
25-foot buffer provided?	--				
Erosion and sedimentation control considered?	8,9				
Maintenance accounted for and plan provided?	10				

➢ *Denotes Minimum Design Consideration*

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AMEC Earth and Environmental Center for Watershed Protection, et al. *Georgia Stormwater Management Manual*, 2001.

Brown, W. and T. Schueler. *The Economics of Stormwater BMPs in the Mid-Atlantic Region*. Ellicott City, MD: Center for Watershed Protection, 1997.

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BMP Fact Sheet

DETENTION BASINS - UNDERGROUND DETENTION

An Underground Detention system is a type of detention basin that is completely underground.

Figure 1 Photograph courtesy of Vertex Design Group

Variations
- Underground Detention Beds
- Underground Vaults

Key Design Features
- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Relatively impermeable soils or impermeable liner
- Forebay for sediment collection and removal
- Stabilized emergency overflow and energy dissipation at all outlets

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	Yes
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Stormwater Quality Functions

Type	TSS	TP	TN	Temperature
Underground Detention	N/A	N/A	N/A	N/A

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Under-ground Detention	Above	N/A	Low/ Med	Yes w/ considerations	30	Dual use, good peak rate performance, wide applicability (including ultra-urban and redevelopment.)	Low volume/GW recharge and water quality benefits, must be combined with other BMPs, high cost, maintenance considerations

*C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.

Additional Considerations

Cost

- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Underground Detention	Med/High

Winter Performance

- Med/High

Description and Function

Underground systems can be provided in a variety of subsurface structural elements, such as underground aggregate-filled beds or vaults, tanks, large pipes, or other fabricated structures placed in aggregate-filled beds in the soil mantle. All such systems are designed to provide runoff peak rate attenuation as their primary function. Regular maintenance is required, because sediment must be removed from the structures within their respective design periods to ensure detention capacity for subsequent rainfall events.

Applications

Detention systems can be used in a wide variety of applications when the necessary space is available. Their use is limited in ultra-urban areas and some redevelopment projects simply due to a lack of available space (in these cases underground and/or special detention may be used).

Variations

Underground detention

These facilities are usually intended for applications on sites where space is limited and are not intended to provide significant water quality treatment. Examples include:

Underground detention beds
Underground detention beds can be constructed by excavating a broad area and filling it with uniformly graded aggregate. Runoff can be stored within the void spaces of the aggregate while the aggregate bed structurally supports overlying land uses.

- Storage design and routing methods are the same as for surface detention basins.
- Underground detention beds may be used where space is limited, but subsurface infiltration is not feasible due to high water table conditions, shallow soil mantle, or poorly draining soils.
- Underground detention beds provide minimal water quality treatment and should

be used in combination with a pretreatment BMP.

- Except where runoff is, or may become toxic and contamination of soil or the water table below the site is possible, underground detention beds should not be lined with an impervious geomembrane. By not installing a geomembrane, a minimal amount of infiltration may still occur. If infiltration is allowed, proper pretreatment is necessary to avoid polluting groundwater. See the infiltration practices BMP for more information.

Underground vaults

Underground vaults are stormwater storage facilities usually constructed of precast reinforced concrete or a structural high density polyethylene plastic system. Tanks are usually constructed of large diameter metal or plastic pipe. Concrete, metal, or plastic pipes may also be installed with no slope as part of a network designed for storage.

- Storage design and routing methods are the same as for surface detention basins.
- Underground detention beds may be used where space is limited but subsurface infiltration is not feasible due to high water table conditions, a shallow soil mantle, or poorly draining soils.
- Underground vaults provide minimal water quality treatment and should be used in combination with a pretreatment BMP.

Design Considerations

Hydrology

- Underground detention basins should be designed to mitigate peak runoff rates for the 1-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the local Stormwater Ordinance. Typically, the NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.

Storage volume, depth, and duration

- If water quality treatment is one of the objectives of the system, the underground detention basins should be designed to treat the runoff volume produced by the water quality design storm, unless additional upstream BMPs are provided.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin.

Detention basin location

- Underground detention basins should be located down gradient of disturbed or developed areas on the site. The basin should collect as much site runoff as possible, especially from the site’s impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Basins should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a basin.
- Basins should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a basin.
- Basins should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Detention basins should not be constructed in areas with high quality and/or well-draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Outlet design

- The low-flow orifice should typically be no smaller than 4 inches in diameter. However, the orifice diameter may be reduced to 2 inches if adequate protection from clogging is provided.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash rack or other mechanism.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.
- Cleanouts or inlets should be installed at a few locations within the system at appropriate intervals to allow access to the piping network and/or storage media and complete removal of accumulated sediment.

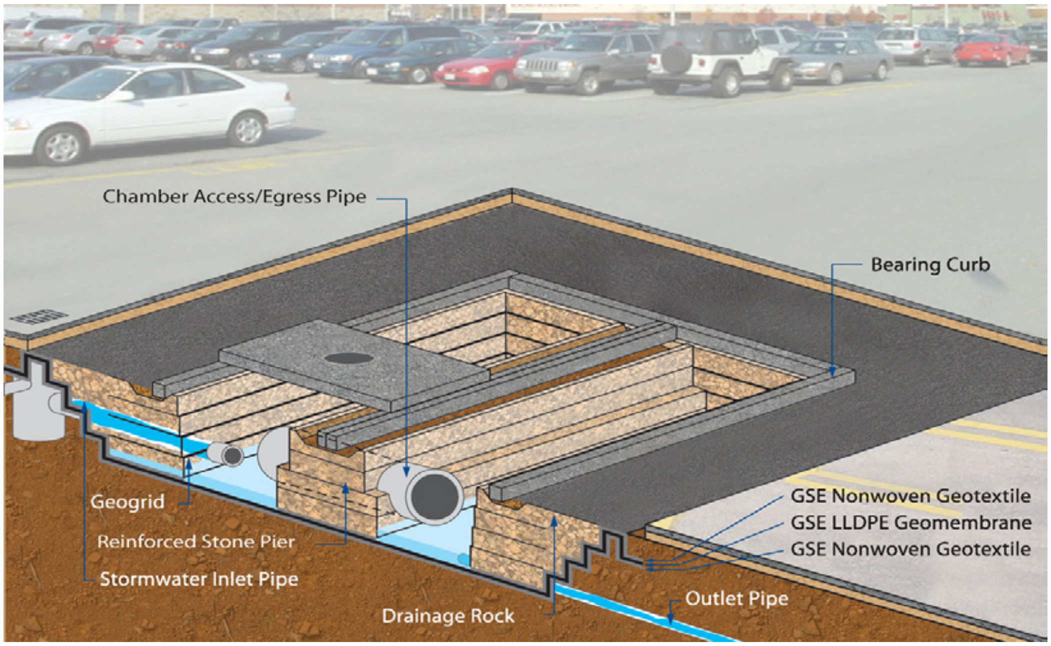

Figure 2 Schematic of underground detention facility, courtesy of CETCO Contracting Services

Vegetation and soils protection

- Underground systems that provide storage within the void space of a stone layer should be wrapped (bottom, top, and sides) in nonwoven geotextile filter fabric to prevent migration of the subsoils into the voids.
- Control of sediment is critical. Rigorous erosion and sediment control measures are required to prevent sediment deposition within the underground system. Nonwoven geotextile may be folded over the edge of the system until the site is stabilized. To minimize maintenance and prevent siltation of the system, pretreatment devices are strongly recommended.
- Aggregate, if used for storage, should be clean, durable and contain a high percentage of void space (typically 40 percent).
- Perforated pipes, if used to distribute runoff to/from the system, should connect structures (such as cleanouts and inlet boxes).

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Underground structures

Site preparation

All excavation areas and structure locations should be cleared and grubbed as necessary.

Where feasible, trees and other native vegetation should be protected, even in areas where temporary inundation is expected. A minimum 10-foot radius around the inlet and outlet structures can be cleared to allow room for construction.

Any cleared material should be used as mulch for erosion control or soil stabilization.

Care should be taken to prevent compaction of the bottom of the reservoir. If compaction should occur, soils should be restored and amended.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should fill completely all spaces under and adjacent to the pipe. At no time during the backfilling operation should driving equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.

- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

Corrugated metal pipe – All of the following criteria should apply for corrugated metal pipe:

- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.
- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Reinforced concrete pipe - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Plastic pipe

- Materials – PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM standards. Corrugated High Density Polyethylene (HDPE) pipe, couplings, and fittings should meet AASHTO specifications.

- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other

unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.

- Backfilling should conform to "structure backfill."
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

Drainage diaphragms – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Operation and maintenance

An operation and maintenance plan in accordance with local or state regulations must be prepared for all underground detention basins. At a minimum, include a dam and inspection checklist as part of the operation and maintenance plan and perform at least annually.

Stormwater Functions and Calculations

Volume reduction

Underground detention systems do not provide an appreciable amount of volume reduction.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled in detention facilities through the transient storage above any permanent water surface. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

Underground detention facilities are usually intended for applications on sites where space is limited and are not intended to provide significant water quality treatment. When appropriate, underground detention may incorporate infiltration practices. For limitations refer to Infiltration Considerations (Introduction to Structural BMPs).

Construction Guidelines

Underground detention systems should be installed per the manufacturer's recommendations.

Maintenance

Underground detention facilities must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

Maintenance activities required for underground detention systems focus on regular sediment and debris removal. All catch basins, inlets, and pretreatment devices draining to the underground bed should be inspected and cleaned at least two times per year. The underground bed and its outlet should be inspected at least once per year and cleaned as needed. A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.

- Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots, such as fueling stations or areas with high pollutant concentrations, should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.

- The underground detention drain should be inspected and tested four times per year.

- Inspections should assess the inlet/ outlet conditions and sediment/debris accumulation.

Cost

The construction cost of underground detention can vary greatly depending on the design, configuration, location, storage volume and media, and site specific conditions, among other factors. Typical construction costs are approximately $8 to $10 per cubic foot for proprietary high capacity storage systems. Systems using uniformly graded aggregate as the primary storage media will typically be less expensive but require additional area and/or depth for an equivalent storage volume.

Designer/Reviewer Checklist for Underground Detention

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for water quality and groundwater recharge?	1,4				
Stable inflow points provided?	4				
Pretreatment provided for sediment removal?	5				
Properly designed outlet structure?	4				
Adequate cleanouts/maintenance access provided?	5				
Stable emergency overflow and outflow points?	--				
Drawdown time less than 36 hours for 90% of stored volume?	--				
Soil compaction minimized?	5				
Clean, washed, open-graded aggregate specified, if applicable?	5				
Geotextile specified?	5				
If proprietary storage media is used, were the manufacturer recommendations followed?	--				
Appropriate native plants selected, if applicable?	--				
Erosion and sedimentation control considered?	5				
Maintenance accounted for and plan provided?	7				

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AMEC Earth and Environmental Center for Watershed Protection, et al. *Georgia Stormwater Management Manual*, 2001.

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BMP Fact Sheet

DETENTION BASINS - WET POND

Wet Ponds, also called wet-bottom detention ponds, are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding while providing a permanent pool of water for aesthetics, recreation, and settlement of sediments.

Figure 1 Pond collecting runoff from rooftops, sidewalks, and yards, Wilsonville, Oregon (USEPA, picasaweb)

Key Design Features

- Wet Ponds
- Wet Detention Ponds
- Pocket Wet Ponds

Key Design Features

- Storage capacity highly dependent on available site area
- Outlet structure configuration determines peak rate reduction effectiveness
- Regular maintenance of vegetation and sediment removal required
- Natural high groundwater table required
- Relatively impermeable soils or impermeable liner
- Forebay for sediment collection and removal
- Dewatering mechanism required
- Stabilized emergency overflow and energy dissipation at all outlets

Applications	
Residential	Yes
Commercial	Yes
Ultra Urban	No
Industrial	Yes
Retrofit	Yes
Highway/Road	Yes
Recreational	Yes

Stormwater Quantity Functions	
Volume	Low
Groundwater Recharge	None or Low
Peak Rate	High

Stormwater Quality Functions

Type	TSS	TP	TN	Temperature
Wet Pond	High	Medium	Medium	Low/Medium

Site Factors

Type	Basin Bottom Relative to Water Table	Soils	Slope	Potential Hotspots	Max. Drainage Area (acres)	Benefits	Limitations
Wet Pond	Can be below WT	C or D*	Low	Yes w/ considerations	50	Good peak rate & TSS performance, wide applicability, potential aesthetic value; can be used as temporary sediment basin	Low volume/GW recharge benefits, high total cost, potentially thermal impact

*C or D soils typically work without modification. A and B soils may require modifications to reduce their permeability.

Additional Considerations

Cost

- High – Cost for above ground basins must include excavation of basin, construction of berm, and installation of storm sewer conveyance system, including pipes and structures. Additional cost may be added for enhanced vegetation.
- The cost of each basin is highly dependent on the size of the basin and site characteristics.

Maintenance

Type	Maintenance
Wet Pond	Low/Med

Winter Performance

- Med/High

Description and Function

Wet ponds are earthen structures that provide temporary storage of runoff and release the stored volume of water over time to help reduce flooding. They are constructed either by impounding a natural depression or excavating existing soil, and are intended to enhance the settlement process in order to maximize water quality benefits, while achieving reduced runoff volume.

Wet ponds include a permanent pool for water quality treatment and additional capacity above the permanent pool for temporary storage. The pond perimeter should generally be covered by a dense stand of emergent wetland vegetation. While they do not achieve significant groundwater recharge or volume reduction, wet ponds can be effective for pollutant removal and peak rate mitigation.

Wet ponds can also provide aesthetic and wildlife benefits. Wet ponds require an adequate source of inflow to maintain the permanent water surface. Due to the potential to discharge warm water, wet ponds should be used with caution near temperature-sensitive water bodies. Properly designed and maintained wet ponds generally do not support significant mosquito populations.

Applications

Wet ponds can be used in a wide variety of applications when the necessary space is available. Their use is limited in ultra urban areas and some redevelopment projects simply due to a lack of available space (in these cases underground and/or special detention may be used).

Variations

Wet ponds can be designed as either online or offline facilities. They can also be used effectively in series with other sediment-reducing BMPs, such as vegetated filter strips, swales, and filters. Wet ponds may be a good option for retrofitting existing dry detention basins. Wet ponds are often organized into the following three groups:

- **Wet ponds** primarily accomplish water quality improvement through displacement of the permanent pool and are generally only effective for small inflow volumes (often they are placed offline to regulate inflow).
- **Wet detention ponds** are similar to wet ponds but use extended detention as another mechanism for water quality and peak rate control. (Discussion of wet ponds in this BMP section focuses on wet detention ponds as described above because this tends to be the most common and effective design.)
- **Pocket wet ponds** are smaller wet ponds that serve drainage areas between approximately 5 and 10 acres and are constructed near the water table to help maintain the permanent pool. They often include extended detention.

Design Considerations

Hydrology

- Wet ponds should be designed to mitigate peak runoff rates for the 1-year through 100-year rainfall events.
- Inflow and discharge hydrographs should be calculated for each selected design storm. Hydrographs should be based on the 24-hour rainfall event or that required in the local Stormwater Ordinance. Typically, the NRCS 24-hour Type II rainfall distribution should be utilized to generate hydrographs.
- Wet ponds must be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. A permanent water surface in the deeper areas of the wet pond should be maintained during all but the driest periods. A relatively stable permanent water surface elevation will reduce the stress on vegetation in an area adjacent to the pond. A wet pond should have a drainage area of at least 10 acres (5 acres for pocket wet ponds) or some means of sustaining constant inflow. Even with a large drainage area, a constant source of inflow can improve the biological health and effectiveness of a wet pond while discouraging mosquito growth.

Storage volume, depth, and duration

- Wet ponds should be designed to treat the runoff volume produced by the water quality design storm unless additional upstream BMPs are provided.
- Detention time is defined as the time from when the maximum storage volume is reached until only 10 percent of that volume remains in the basin. In order to achieve an 80 percent total suspended solids removal rate, a 36-hour detention time is required, with no more than 40% of the maximum stored volume released within the first 12 hours.

Additional design considerations for extended detention (Figure 2)

The low flow orifice should be sized and positioned to detain the calculated water quality runoff volume for at least 24 hours, but no more than 36 hours. The low flow orifice may be allowed as small as 4 inches in diameter if adequate protection from clogging is provided.

Basin sizing and configuration

- Wet ponds should be shaped to maximize the hydraulic length of the stormwater flow pathway. A minimum length-to width ratio of 3:1 is recommended to maximize sedimentation. If the length-to-width ratio is lower, the flow pathway should be maximized. A wedge-shaped pond with the major inflows on the narrow end can prevent short-circuiting and stagnation.
- Irregularly shaped basins are acceptable and may even be encouraged to improve site aesthetics.
- Distances of flow paths from inflow points to outlets should be maximized.
- If site conditions inhibit construction of a long, narrow basin, baffles consisting of earthen berms or other materials can be incorporated into the pond design to lengthen the stormwater flow path.
- Basins must have one or more sediment forebays or equivalent upstream pretreatment to trap coarse sediment, prevent short circuiting and facilitate maintenance (i.e., sediment removal). The forebay should consist of a separate cell, formed by a

structural barrier. The forebay will require periodic sediment removal.

- Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least nine feet wide, having a maximum slope of 15 percent, and be stabilized for vehicles.
- An emergency outlet or spillway capable of conveying the spillway design flood (SDF) must be included in the design. The SDF is usually equal to the 1.25 times the 100-year design flood.
- The area required for a wet pond is generally one to three percent of its drainage area. Wet ponds should be sized to treat the water quality volume and to mitigate the peak rates for larger events.
- All areas that are deeper than four feet should have two safety benches, totaling 15 feet in width. One should start at the normal water surface and extend up to the pond side slopes at a maximum slope of 10 percent. The other should extend from the water surface into the pond to a maximum depth of 18 inches, also at slopes no greater than 10 percent.
- Slopes in and around wet ponds should be 4:1 to 5:1 (horizontal: vertical) or flatter whenever possible (10:1 max. for safety/aquatic benches).

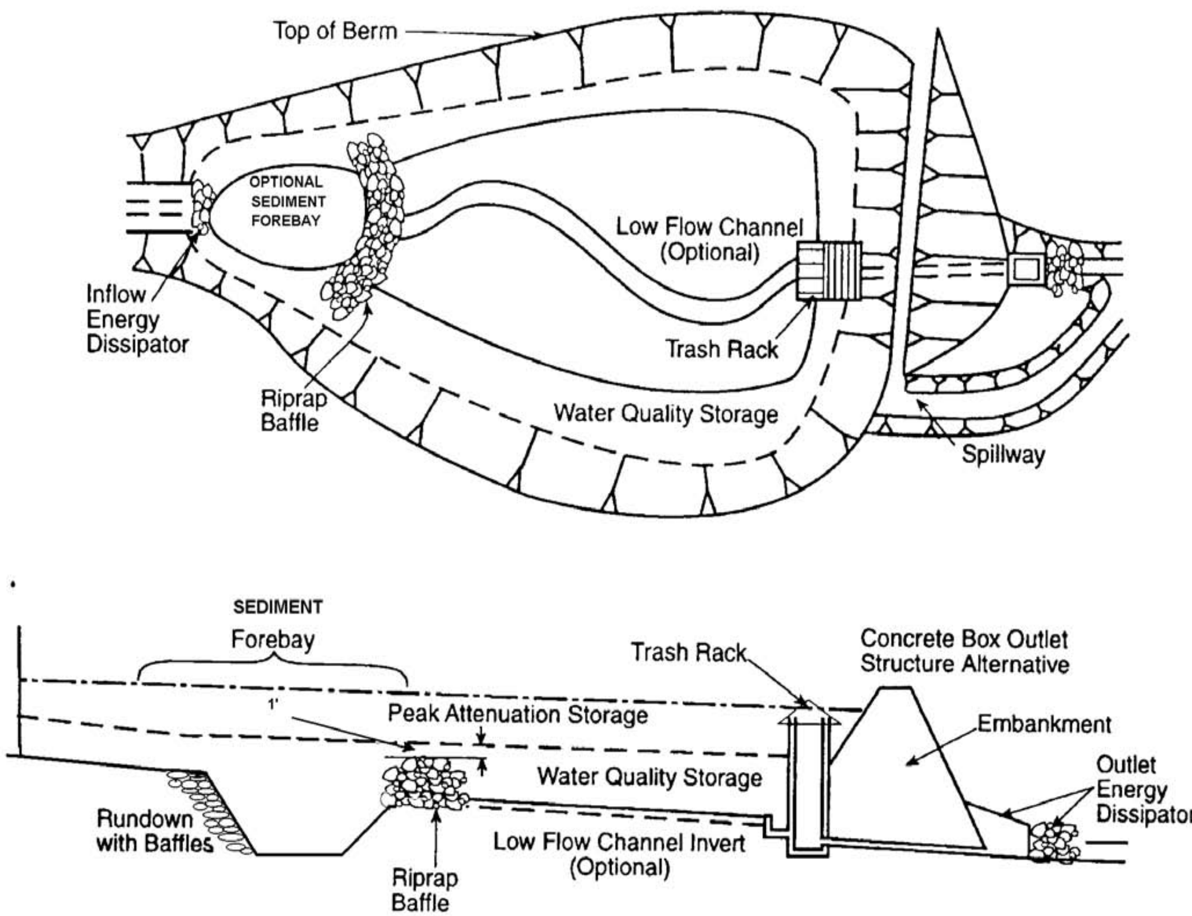

Figure 2 Extended detention basin
Source: New Jersey BMP Manual

Embankments

- Vegetated embankments less than or equal to three feet in height are recommended. Embankments should have side slopes no steeper than 3:1 (horizontal to vertical).
- The basin should have a minimum freeboard of one foot above the SDF elevation to the top of the berm.
- Woody vegetation is generally discouraged in the embankment area because of the risk of compromising the integrity of the embankment.
- Embankments should incorporate measures, such as buried chain link fencing, to prevent or discourage damage from tunneling wildlife (e.g., muskrat).

Wet pond location

- Wet ponds should be located down gradient of disturbed or developed areas on the site. The wet pond should collect as much site runoff as possible, especially from the site's impervious surfaces (roads, parking, buildings, etc.), and where other BMPs are not proposed.
- Wet ponds should not be constructed on steep slopes, nor should slopes be significantly altered or modified to reduce the steepness of the existing slope, for the purpose of installing a wet pond.
- Wet ponds should not worsen the runoff potential of the existing site by removing trees for the purpose of installing a wet pond
- Wet ponds should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system.
- Wet ponds should not be constructed in areas with high quality and/or well draining soils, which are adequate for installing BMPs capable of achieving stormwater infiltration and, hence, volume reduction.

Additional design considerations for extended detention (Figure 2)

- Wet detention ponds should not be constructed within jurisdictional waters, including wetlands, or their regulated buffers.

Outlet design

- The low-flow orifice should typically be no smaller than 4 inches in diameter. However, the orifice diameter may be reduced to two inches if adequate protection from clogging is provided.
- The hydraulic design of all outlet structures must consider any significant tailwater effects of downstream waterways.
- The primary and low flow outlets should be protected from clogging by an external trash rack or other mechanism.

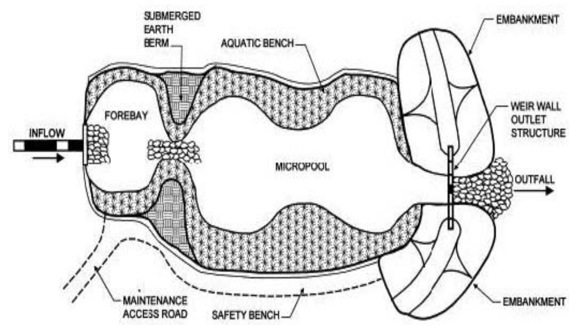

Figure 3 Pocket wet pond
Source: Maryland Stormwater Manual, 2000

- Online facilities should have an emergency spillway that can safely pass the 1.25 times the 100-year storm with one foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.
- When designed to meet discharge criteria for a range of storms, basins should incorporate a multistage outlet structure. Three elements are typically included in this design:
  - An outlet that controls the extended detention and functions to slowly release the water quality or channel protection design storm.
  - A primary outlet that functions to attenuate the peak of larger design storms.
  - An emergency overflow outlet/spillway. The emergency spillway should be at the top of the berm.
- The primary outlet structure should incorporate weirs, orifices, pipes, or a combination of these to control runoff peak rates for multiple design storms. Water quality storage should be provided above the permanent pool elevation. When routing

basins, the water quality outlet should be included in the depth-discharge relationship.

- Energy dissipaters should be placed at the end of the primary outlet to prevent erosion. If the basin discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone between the outlet and natural channel. Where feasible, a multiple orifice outlet system is preferred to a single pipe.

Inlet structures

- Erosion protection measures should be used to stabilize inflow structures and channels.

Sediment forebay

- Forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.
- Forebays must be incorporated into the basin design. Forebays should be provided at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the main basin, and minimize erosion by inflow.
- Forebays should be vegetated to improve filtering of runoff, to reduce runoff velocity, and to stabilize soils against erosion. Forebays should adhere to the following criteria:
  - A minimum length of 10 feet.
  - Storage should be provided to trap sediment over from storms with return periods between 1 and 10 years.
  - Forebays should be physically separated from the rest of the pond by a berm, gabion wall, etc.
  - Flows exiting the forebay must be non-erosive to the newly constructed basin.
  - Forebays should be installed with permanent vertical markers that indicate sediment depth.
  - Storage volume of 10 to 15 percent of the total permanent pool volume and is four to six feet deep.
  - All major inflow points to dry detention basins should include sediment forebays sized for 10 percent of the water quality volume.

Vegetation and soils protection

- Underlying soils must be identified and tested. Generally, hydrologic soil groups “C” and “D” are suitable without modification, though “A” and “B” soils may require modification to reduce their natural permeability. Soil permeability must be tested in the proposed wet pond location to ensure that excessive infiltration will not cause the wet pond to dry out.
- Organic soils should be used for shallow areas within wet ponds. Organic soils can serve as a sink for pollutants and generally have high water holding capacities. They will also facilitate plant growth and propagation and may hinder invasion of undesirable species. Care must be taken to ensure that soils used are free of invasive or nuisance plant seeds.
- To enhance habitat value, visual aesthetics, water temperature, and pond health, a 25-foot buffer should be provided, measured outward from the maximum water surface elevation. The buffer should be planted with trees, shrubs, and native ground covers. Except in maintenance access areas, turf grass should not be used. Existing trees within the buffer should be preserved. If soils in the buffer will become compacted during construction, soil restoration should take place to aid buffer vegetation.

General Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

Excavation

- The area to be used for the wet pond should be excavated to the required depth below the desired bottom elevation to accommodate any required impermeable liner, organic matter, and/or planting soil.

- The compaction of the subgrade and/or the installation of any impermeable liners will follow immediately.

Subsoil preparation

- Subsoil should be free from hard clods, stiff clay, hardpan, ashes, slag, construction debris, petroleum hydrocarbons, or other undesirable material. Subsoil must not be delivered in a frozen or muddy state.
- Scarify the subsoil to a depth of 8 to 10 inches with a disk, rototiller, or similar equipment.
- Roll the subsoil under optimum moisture conditions to a dense seal layer with four to six passes of a sheepsfoot roller or equivalent. The compacted seal layer should be at least eight inches thick.

Impermeable liner

- If necessary, install impermeable liner in accordance with manufacturer's guidelines.
- Place a minimum 12 inches of subsoil on top of impermeable liner in addition to planting soil.
- May be required when in proximity to a public water supply. See Infiltration Considerations (Introduction to Structural BMPs).

Earth fill material & placement

- The fill material should be taken from approved designated excavation areas. It should be free of roots, stumps, wood, rubbish, stones greater than six inches, or other objectionable materials. Materials on the outer surface of the embankment must have the capability to support vegetation.
- Areas where fill is to be placed should be scarified prior to placement. Fill materials for the embankment should be placed in maximum eight-inch lifts. The principal spillway must be installed concurrently with fill placement and not excavated into the embankment.
- Control movement of the hauling and spreading equipment over the site.

Embankment core

- The core should be parallel to the centerline of the embankment as shown on the plans. The top width of the core should be at least four feet. The height should extend up to at least the 10-year water elevation or as shown on the plans. The side slopes should be 1:1 or flatter. The core should be compacted with construction equipment, rollers, or hand tampers to assure maximum density and minimum permeability. The core should be placed concurrently with the outer shell of the embankment.
- Construction of the berm should follow specifications by the project's geotechnical engineer.

Structure backfill

- Backfill adjacent to pipes and structures should be of the type and quality conforming to that specified for the adjoining fill material. The fill should be placed in horizontal layers not to exceed eight inches in thickness and compacted by hand tampers or other manually directed compaction equipment. The material should completely fill all spaces under and adjacent to the pipe. At no time during the backfilling operation should driving equipment be allowed to operate closer than four feet to any part of the structure. Equipment should not be driven over any part of a concrete structure or pipe, unless there is a compacted fill of 24 inches or greater over the structure or pipe.
- Backfill content and placement should follow specifications by the project's geotechnical engineer.

Pipe conduits

<u>Corrugated metal pipe</u> – All of the following criteria should apply for corrugated metal pipe:

- Materials – Polymer coated steel pipe, aluminum coated steel pipe, aluminum pipe. This pipe and its appurtenances should conform to the requirements of AASHTO specifications with watertight coupling bands or flanges.

- Coupling bands, anti-seep collars, end sections, etc., must be composed of the same material and coatings as the pipe. Metals must be insulated from dissimilar materials with use of rubber or plastic insulating materials at least 24 mils in thickness.
- Connections – All connections with pipes must be completely watertight. The drain pipe or barrel connection to the riser should be welded all around when the pipe and riser are metal. Anti-seep collars should be connected to the pipe in such a manner as to be completely watertight. Dimple bands are not considered to be watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

<u>Reinforced concrete pipe</u> - All of the following criteria should apply for reinforced concrete pipe:

- Materials – Reinforced concrete pipe should have bell and spigot joints with rubber gaskets and should equal or exceed ASTM standards.
- Laying pipe – Bell and spigot pipe should be placed with the bell end upstream. Joints should be made in accordance with recommendations of the manufacturer of the material. After the joints are sealed for the entire line, the bedding should be placed so that all spaces under the pipe are filled. Take care to prevent any deviation from the original line and grade of the pipe.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

<u>Plastic pipe</u>

- Materials – PVC pipe should be PVC-1120 or PVC-1220 conforming to ASTM standards. Corrugated High Density Polyethylene (HDPE) pipe, couplings, and fittings should meet AASHTO specifications.
- Joints and connections to anti-seep collars should be completely watertight.
- Bedding – The pipe should be firmly and uniformly bedded throughout its entire length. Where rock or soft, spongy or other unstable soil is encountered, all such material should be removed and replaced with suitable earth compacted to provide adequate support.
- Backfilling should conform to “structure backfill.”
- Other details (anti-seep collars, valves, etc.) should be as shown on drawings.

<u>Drainage diaphragms</u> – When a drainage diaphragm is used, a registered professional engineer must supervise the design and construction inspection.

Planting soil (topsoil)

- See local specifications for general planting soil requirements.
- Use a minimum of 12 inches of topsoil in the emergent vegetation zone (less than 18” deep) of the pond. If natural topsoil from the site is to be used it must have at least eight percent organic carbon content (by weight) in the A-horizon for sandy soils and 12 percent for other soil types.
- If planting soil is imported, it should be made up of equivalent proportions of organic and mineral materials. All soils used should be free of invasive or nuisance seeds.
- Lime should not be added to planting soil unless absolutely necessary as it may encourage the propagation of invasive species.
- The final elevations and hydrology of the vegetative zones should be evaluated prior to planting to determine if grading or planting changes are required.

Vegetation

- See Recommended Plant List for BMPs Appendix for plant lists for wet ponds. Substitutions of specified plants should be subject to prior approval of the designer. Planting locations should be based on the planting plan and directed in the field by a qualified wetland ecologist. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

- All wet pond plant stock should exhibit live buds or shoots. All plant stock should be turgid, firm, and resilient. Internodes of rhizomes may be flexible and not necessarily rigid. Soft or mushy stock should be rejected. The stock should be free of deleterious insect infestation, disease, and defects such as knots, sun-scald, injuries, abrasions, or disfigurement that could adversely affect the survival or performance of the plants.
- All stock should be free from invasive or nuisance plants or seeds.
- During all phases of the work, including transport and onsite handling, the plant materials should be carefully handled and packed to prevent injuries and desiccation. During transit and onsite handling, the plant material should be kept from freezing and be covered, moist, cool, out of the weather, and out of the wind and sun. Plants should be watered to maintain moist soil and/or plant conditions until accepted.
- Plants not meeting these specifications or damaged during handling, loading, and unloading will be rejected.

Outlet control structure

- Outlet control structures should be constructed of non-corrodible material.
- Outlets should be resistant to clogging by debris, sediment, floatables, plant material, or ice.
- Materials should comply with applicable specifications (INDOT or AASHTO, latest edition).

Stormwater Functions and Calculations

Volume reduction

Although not typically considered a volume-reducing BMP, wet ponds can achieve some volume reduction through infiltration and evapo-transpiration, especially during small storms and high temperature periods.

According to the International Stormwater BMP Database, wet ponds have an average annual volume reduction of seven percent (Strecker et al., 2004). Hydrologic calculations should be performed to verify that the wet pond will have a viable amount of inflow and to predict the water surface elevation under varying conditions. The volume stored between the predicted water level and the lowest outlet elevation will be removed from the storm that occurs under those conditions.

Peak rate mitigation

Inflow and discharge hydrographs must be calculated for each design storm.

Peak rate is primarily controlled in detention facilities through the transient storage above any permanent water surface. The degree to which peak rate is controlled is a function of the transient storage volume provided (i.e., depth and area) and the configuration of the outlet control structure.

Water quality improvement

Wet ponds rely on physical, biological, and chemical processes to remove pollutants from influent stormwater runoff. The primary treatment mechanism is settling by gravity of particulates and their associated pollutants while stormwater is retained in the pond. Another mechanism for the removal of pollutants, especially nutrients, is uptake by algae and aquatic vegetation. Typical pollutant removal efficiencies are provided in the Post-Construction Stormwater Quality Management Chapter of the Technical Standards.

The longer the runoff remains in a wet pond, the more settling (and associated pollutant removal) and other treatment can occur. After the particulates reach the bottom, the permanent pool protects them from resuspension when additional runoff enters.

The long detention or retention time associated with wet ponds can be problematic in coldwater fisheries due to the potential increase in water temperature. In these situations, detention times should be limited to a maximum of 12 hours, or other treatment alternatives (e.g., infiltration) should be explored.

Construction Guidelines

The following guidelines pertain to wet ponds:

- Install all temporary erosion and sedimentation controls.
- Separate pond area from contributing drainage area.
- All channels/pipes conveying flows to the pond must be routed away from the pond area until it is completed and stabilized.
- The area immediately adjacent to the pond must be stabilized in accordance with the erosion and sediment control methods discussed in the Erosion and Sediment Control Requirements Chapter of the Technical Standards and the latest requirements of IDEM’s Soil Erosion and Sedimentation Control Program prior to construction of the pond (Rule 5).
- Prepare site for excavation and/or embankment construction.
- All existing vegetation should remain if feasible and only be removed if necessary for construction.
- Care should be taken to prevent compaction of the basin bottom.
- If excavation is required, clear the area of all vegetation. Remove all tree roots, rocks, and boulders only in excavation area.
- Excavate bottom of basin to desired elevation (if necessary).
- Install surrounding embankments and inlet and outlet control structures.
- Grade and prepare subsoil in bottom of basin. Compact bottom of basin in wet ponds.
  - Apply and grade planting soil. Matching design grades is crucial in wet ponds because aquatic plants can be very sensitive to depth.
  - Apply geo-textiles and other erosion-control measures.
- Seed, plant, and mulch according to landscaping plan.
- Install any safety or anti-grazing measures, if necessary.
- Follow required maintenance and monitoring guidelines.

Maintenance

Wet ponds must have a maintenance plan and privately owned facilities should have an easement, deed restriction, or other legal measure to prevent neglect or removal.

A basin maintenance plan should be developed which includes the following measures:

- All basin structures should be inspected for clogging and excessive debris and sediment accumulation at least four times per year, as well as after every storm greater than one inch. Structures that should be inspected include basin bottoms, trash racks, outlets structures, riprap or gabion structures, and inlets.

- Sediment should be removed from the forebay before it occupies 50 percent of the forebay, typically every 3 to 10 years. Sediment removal should be conducted when the basin is completely dry.

- Wet ponds should be drained prior to sediment removal. Sediment should be disposed of properly and once sediment is removed, disturbed areas need to be immediately stabilized and re-vegetated. Proper disposal of removed material depends on the nature of the drainage area and the intent and function of the detention basin. Material removed from detention basins that treat hot spots, such as fueling stations or areas with high pollutant concentrations, should be disposed according to IDEM regulations for solid waste. Detention basins that primarily catch sediment from areas such as lawns may redistribute the waste on site.

- The pond drain should be inspected and tested four times per year.

- The embankment should be inspected for evidence of tunneling or burrowing wildlife at least twice during the growing season. If damage is found, the damage should be repaired and the animals removed.

- Mowing and/or trimming of vegetation should be performed as necessary to sustain the system, but all detritus must be removed from the basin. Embankment should be mowed 1–2 times per year to prevent the establishment of woody vegetation.

- Inspections should assess the vegetation, erosion, flow channelization, bank stability, inlet/outlet conditions, embankment, and sediment/debris accumulation.

- Vegetated areas should be inspected annually for unwanted growth of invasive species.

- Vegetative cover should be maintained at a minimum of 85 percent.

Winter Considerations

One of the biggest problems associated with proper wet pond operation during cold weather is the freezing and clogging of inlet and outlet pipes. To avoid these problems, the Center for Watershed Protection (Caraco and Claytor, 1997) made some general design suggestions, which are adapted as follows:

- Inlet pipes should typically not be submerged, since this can result in freezing and upstream damage or flooding.

- Burying all pipes below the frost line can prevent frost heave and pipe freezing. Wind protection can also be an important consideration for pipes above the frost line. In these cases, designs modifications that have pipes "turn the corner" are helpful.

- Incorporate lower winter operating levels as part of the design to introduce available storage for melt events.

- Increase the slope of inlet pipes to a minimum of one percent to prevent standing water in the pipe, reducing the potential for ice formation. This design may be difficult to achieve at sites with flat local slopes.

- If perforated riser pipes are used, the minimum opening diameter should be ½-inch. In addition, the pipe should have a minimum eight-inch diameter.

- When a standard weir is used, the minimum slot width should be three inches, especially when the slot is tall.

- Baffle weirs can prevent ice reformation during the spring melt near the outlet by preventing surface ice from blocking the outlet structure.

- In cold climates, riser hoods should be oversized and reverse slope pipes should draw from at least six inches below the typical ice layer.

- Alternative outlet designs that have been successful include using a pipe encased in a gravel jacket set at the elevation of the aquatic bench as the control for water-quality events. This practice both avoids stream warming and serves as a non-freezing outlet.

- Trash racks should be installed at a shallow angle to prevent ice formation. Constructed wetland performance can be decreased in spring months when large volumes of runoff occur in a relatively short time carrying the accumulated pollutant load from the winter months. Since constructed wetlands are relatively shallow, freezing of the shallow pool can occur.

Cost

The construction cost of wet ponds varies greatly depending on the configuration, location, site specific conditions, etc. Typical construction costs in 2007 dollars range from approximately $30,000 to $60,000 per acre-foot of storage (based on USEPA, 1999). Alternately, the construction cost of a wet pond can be estimated as $6,000 per acre of contributing drainage area. Costs are generally most dependent on the amount of earthwork and the planting.

In addition to the water resource protection benefits of wet ponds, there is some evidence to suggest that they may provide an economic benefit by increasing property values. The results of one study suggest that “pond front” property can increase the selling price of new properties by about 10 percent (USEPA, 1995). Another study reported that the perceived value (i.e., the value estimated by residents of a community) of homes was increased by about 15 to 25 percent when located near a wet pond (Emmerling-Dinovo, 1995).

Annual maintenance costs for wet ponds have been reported to be approximately three to five percent of the capital costs, though there is little data available to support this. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems may be spread over a relatively long time period.

Designer/Reviewer Checklist for Wet Detention Ponds

ITEM	Page No.	YES	NO	N/A	NOTES
Used in conjunction with other BMPs for water quality and groundwater recharge?	1				
Adequate drainage area/water supply/groundwater table to maintain permanent water surface? ➢ *Min. drainage area:* ***10 acres, 5 acres for pocket wet pond*** ➢ *Max. drainage area:* ***50 acres***	2-4				
Stable inflow points provided?	6				
Forebay and/or pretreatment provided for sediment removal? ➢ *Min. width of permanent access:* ***9 ft*** ➢ *Max. slope:* ***15%*** ➢ *Min. length of forebay:* ***10 ft***	4,6,7				
Adequate length to width ratio? ➢ *Min. length-to-width ratio:* ***3:1***	4				
Total depth limited? ➢ *Max. depth:* ***10 ft***	8				
Acceptable side slopes? ➢ *Max. slope:* ***10%***	4,5				
Safety benches provided?	4				
Properly designed outlet structure?	6				
Trash rack provided to prevent clogging?	6				
Stable emergency overflow and outflow points?	6				
Drawdown time less than 36 hours for 90% of stored volume?	4				
Soil compaction minimized?	--				
Adequate underlying soils?	7,8				
Appropriate native plants selected?	7,8				
25-foot buffer provided?	7				
Erosion and sedimentation control considered?	11				
Maintenance accounted for and plan provided? ➢ *Min. vegetative cover to be maintained:* ***85%***	12				

➢ *Denotes Minimum Design Consideration*

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BMP Fact Sheet

INFILTRATION PRACTICES

Infiltration practices are natural or constructed land areas located in permeable soils that capture, store, and infiltrate the volume of stormwater runoff into surrounding soil.

Figure 1 Infiltration Bed, Seattle, WA (USEPA, picasaweb)

Variations

- **Dry Wells**, also referred to as seepage pits, French drains or Dutch drains, are a subsurface storage facility (structural chambers or excavated pits, backfilled with a coarse stone aggregate) that temporarily store and infiltrate stormwater runoff from rooftop structures. Due to their size, dry wells are typically designed to handle stormwater runoff from smaller drainage areas, less than one acre in size.
- **Infiltration basins** are shallow surface impoundments that temporarily store, capture, and infiltrate runoff over a period of several days on a level and uncompacted surface. Infiltration basins are typically used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent.
- **Infiltration berms** use a site's topography to manage stormwater and prevent erosion. Berms may function independently in grassy areas or may be incorporated into the design of other stormwater control facilities such as Bioretention and Constructed Wetlands. Berms may also serve various stormwater drainage functions including: creating a barrier to flow, retaining flow for volume control, and directing flows.
- **Infiltration trenches** are linear subsurface infiltration structures typically composed of a stone trench wrapped with geotextile which is designed for both stormwater infiltration and conveyance in drainage areas less than five acres in size.
- **Subsurface infiltration beds** generally consist of a rock storage (or alternative) bed below other surfaces such as parking lots, lawns, and playfields for temporary storage and infiltration of stormwater runoff with a maximum drainage are of 10 acres.
- **Bioretention** can be an infiltration practice and is discussed in the Bioretention BMP.
- **Level spreaders** can be an infiltration practice and are discussed in the Level Spreader BMP.

Key Design Features

- Depth to water table or bedrock
- Pretreatment is often needed to prevent clogging
- Often requires level infiltration surface
- Proximity to buildings, drinking water supplies, karst features, and other sensitive areas
- Soil types
- Provide positive overflow in most uses

Site Factors

- Maximum Site Slope: 20 percent
- Minimum depth to bedrock: Two feet
- Minimum depth to seasonally high water table: Two feet
- Potential Hotspots: Yes, with pretreatment and/or impervious liner
- NRCS Soil Type: A, B, C*, D*

* C & D soils have limited infiltration ability and may require an underdrain

Infiltration BMP	Max. Drainage Area
Berming	5 acres
Dry Well	1 acre
Infiltration Basin	10 acres
Infiltration Trench	2 acres
Subsurface Infiltration Bed	5 acres

Benefits

- Reduces volume of stormwater runoff
- Reduces peak rate runoff
- Increases groundwater recharge
- Provides thermal benefits

Limitations

- Pretreatment requirements to prevent clogging
- Not recommended for areas with steep slopes

Applications

	Residential	Commercial	Ultra Urban	Industrial	Retrofit	Highway/ Road	Recreational
Dry well	Yes	Yes	Yes	Limited	Yes	No	No
Infiltration basin	Yes	Yes	Limited	Yes	Limited	Limited	No
Infiltration berm	Yes	Yes	Limited	Yes	Yes	Yes	No
Infiltration trench	Yes	Yes	Yes	Yes	Yes	Yes	No
Subsurface infiltration bed	Yes	Yes	Yes	Yes	Yes	Limited	No

Stormwater Quantity Functions

	Volume	Groundwater Recharge	Peak Rate
Dry well	Medium	High	Medium
Infiltration basin	High	High	High
Infiltration berm	Low/Medium	Low/Medium	Medium
Infiltration trench	Medium	High	Low/Medium
Subsurface infiltration bed	High	High	High

Stormwater Quality Functions

	TSS	TP	NO3	Temperature
Dry well	High	High/Medium	Medium/Low	High
Infiltration basin	High	Medium/High	Medium	High
Infiltration berm	Medium/High	Medium	TN-Medium	Medium
Infiltration trench	High	High/Medium	Medium/Low	High
Subsurface infiltration bed	High	Medium/High	Low	High

Description and Function

Infiltration practices are designed to store, capture, and infiltrate stormwater runoff into the surrounding soils. During periods of rainfall, infiltrations BMPs reduce the volume of runoff and help to mitigate potential flooding events, downstream erosion, and channel morphology changes. This recharged water serves to provide base-flow to streams and maintain stream water quality.

Infiltration BMPs provide excellent pollutant removal effectiveness because of the combination of a variety of natural functions occurring within the soil mantle, complemented by existing vegetation (where this vegetation is preserved). Soil functions include physical filtering, chemical interactions (e.g., ion exchange, adsorption), as well as a variety of forms of biological processing, conversion, and uptake. The inclusion of appropriate vegetation for some infiltration basins reinforces the work of the soil by reducing velocity and erosive forces, soil anchoring, and further uptake of nonpoint source pollutants. In many cases, even the more difficult-to-remove soluble nitrates can be reduced as well. It should be noted that infiltration BMPs tend to be excellent for removal of many pollutants, especially those that are in particulate form. However, there are limitations to the removal of highly soluble pollutants, such as nitrate, which can be transmitted through the soil.

In addition to the removal of chemical pollutants, infiltration can address thermal pollution. Maintaining natural temperatures in stream systems is recognized as an issue of increasing importance for protection of overall stream ecology. While detention facilities tend to discharge heated runoff flows, the return of runoff to the groundwater through use of infiltration BMPs guarantees that these waters will be returned at natural groundwater temperatures, considerably cooler than ambient air in summer and warmer in winter. As a result, seasonal extreme fluctuations in stream water temperature are minimized. Fish, macro-invertebrates, and a variety of other biota will benefit as the result.

Infiltration Limitations

The use of sediment pretreatment with infiltration BMPs is required for many infiltration BMPs to prevent clogging of the infiltration surface area. Sediment pretreatment can take the form of a water quality filtering device, a settling basin, filter strips, sediment trap, or a combination of these practices upstream of the infiltration practice. Pretreatment practices should be inspected and maintained at least once per year. Before entering an infiltration practice, stormwater should first enter a pretreatment practice sized to treat a minimum volume of 25% of the water quality volume (V_{wq})

Sites that include hot spots, such as gasoline stations, vehicle maintenance areas, and high intensity commercial uses, may need additional pretreatment practices to prevent impairment of groundwater supplies. Infiltration may occur in areas of hot spots provided pretreatment is suitable to address concerns.

Pretreatment devices that operate effectively in conjunction with infiltration include grass swales, vegetated filter strips, bioretention, settling chambers, oil/grit separators, constructed wetlands, sediment sumps, and water quality inserts. Selection of pretreatment practices should be guided by the pollutants of greatest concern, and the extent of the land development under consideration.

Selection of pretreatment techniques will vary depending upon whether the pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus a soluble (nitrogen and others) nature.

Applications

Infiltration systems can be used in a variety of applications, from small areas in residential properties to extensive systems under commercial parking lots or large basins in open space. Industrial, retrofit, highway/ road, and recreational areas can also readily incorporate infiltration to varying degrees. The use of infiltration basins and berming in ultra-urban and redevelopment settings is limited primarily due to space constraints.

Dry wells have limited applicability in industrial settings as they are designed for runoff from relatively small roof areas (therefore they are also not applicable to transportation corridors). Infiltration basins, subsurface infiltration beds, and berming are also limited for transportation projects due to space constraints and grading requirements (however berming can be used to some degree – especially along the edge of the right of way – to capture runoff).

Variations

Subsurface infiltration

A subsurface infiltration bed generally consists of a rock storage (or alternative) bed below other surfaces such as parking lots, lawns and playfields for temporary storage and infiltration of stormwater runoff. Subsurface storage is enhanced with perforated or open bottom piping. Subsurface infiltration beds can be stepped or terraced down sloping terrain, provided that the base of the bed remains level. Stormwater runoff from nearby impervious areas is conveyed to the subsurface storage media, receives necessary pretreatment and is then distributed via a network of perforated piping.

The storage media for subsurface infiltration beds typically consists of clean-washed, uniformly graded aggregate. However, other storage media alternatives are available. These alternatives are generally variations on plastic cells that can more than double the storage capacity of aggregate beds. Storage media alternatives are ideally suited for sites where potential infiltration area is limited.

If designed, constructed, and maintained using the following guidelines, subsurface infiltration features can stand alone as significant stormwater runoff volume, rate, and quality control practices. These systems can also provide some aquifer recharge, while preserving or creating valuable open space and recreation areas. They have the added benefit of functioning year-round, because the infiltration surface is typically below the frost line.

Various methods can be utilized to connect to subsurface infiltration areas:

Connection of roof leaders

> Runoff from nearby roofs can be directly conveyed to subsurface beds via roof leader connections to perforated piping. Roof runoff generally has relatively low sediment levels, making it ideally suited for connection to an infiltration bed.

Connection of inlets

> Catch basins, inlets, and area drains may be connected to subsurface infiltration beds. However, sediment, oil and grease, and debris removal must be provided. Storm structures should include sediment trap areas below the inverts of discharge pipes to trap solids and debris. Parking lots and roadways must provide for the removal of oil and grease and other similar constituents through appropriate treatment. In areas of high traffic or excessive generation of sediment, litter, and other similar materials, a water quality insert or other pretreatment device may be required.

Infiltration trench

An infiltration trench is a linear stormwater BMP consisting of a continuously perforated pipe within a sub-surface stone-filled trench wrapped with geotextile. Usually, an infiltration trench is part of a conveyance system and is designed so that large storm events are conveyed through the pipe with some runoff volume reduction. During small storm events, volume reduction may be significant and there may be little or no discharge.

All infiltration trenches should be designed with a positive overflow. Sediment pretreatment of runoff from impervious areas should be considered to prevent clogging within the trench, particularly when conveying runoff from roadways and parking areas.

An infiltration trench differs from an infiltration bed in that it may be constructed in more confined areas. The designer must still consider the impervious area to infiltration area loading rate. It can be located beneath or within

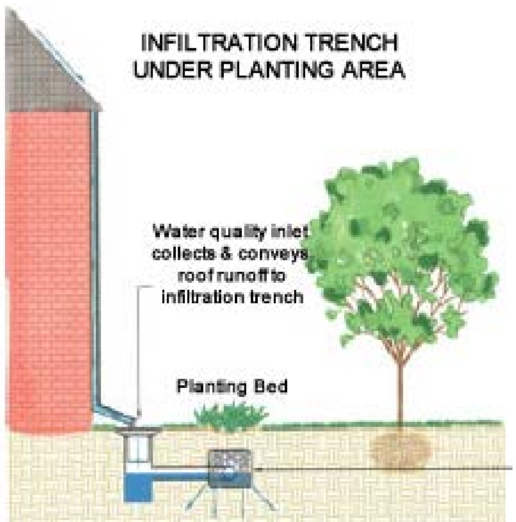

Figure 2 Infiltration trench with continuously perforated pipe for distribution with positive overflow

roadways or impervious areas (**Figure 2**) and can also be located down a mild slope by "stepping" the sections between control structures.

Infiltration basin

Infiltration basins (**Figure 3**) are shallow, impounded areas designed to temporarily store and infiltrate storm-water runoff. The size and shape can vary from one large basin to multiple, smaller basins throughout a site.

Infiltration basins use the existing soil and native vegetation to reduce the volume of stormwater runoff by infiltration and evapotranspiration. Therefore, the use of sediment pretreatment is imperative to prevent clogging of the infiltration surface area within the basin. Sediment pretreatment can take the form of a water quality filtering device, vegetative filter strips, a settling basin, or a sediment trap. The key to promoting infiltration is to provide enough surface area for the volume of runoff to be absorbed within 72 hours.

An engineered overflow structure must be provided for the larger storms and can be designed for peak rate attenuation. With the use of a properly designed outlet structure, infiltration basins can be designed to mitigate volume and water quality for small frequent storms, while managing peak rates for large design storms.

Dry well

A dry well (**Figure 4**) is a subsurface storage facility that temporarily stores and infiltrates stormwater runoff from rooftops. Roof leaders usually connect directly into the dry well, which may be either an excavated pit filled with uniformly graded aggregate wrapped in geotextile or a prefabricated storage chamber or pipe segment. For structures without gutters or

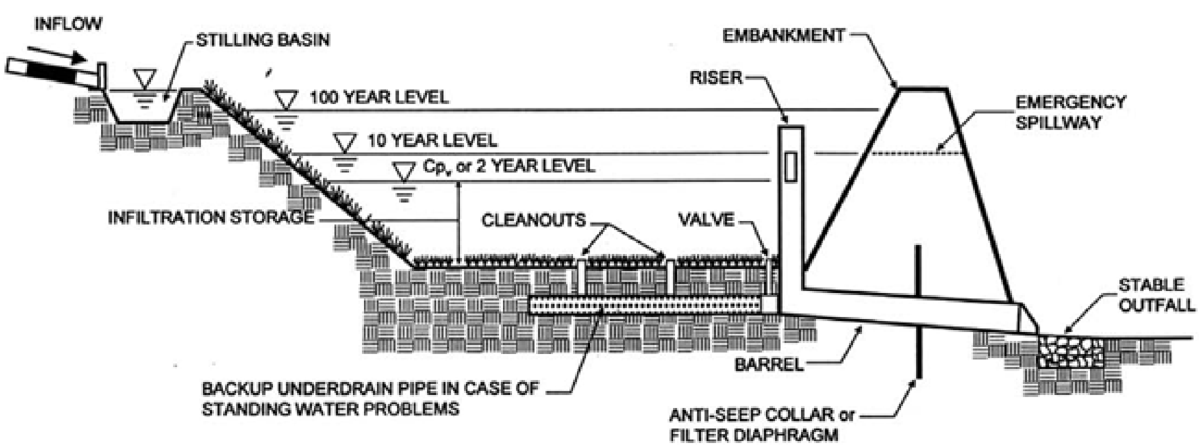

Figure 3 Residential Rain Garden with surface connection to subsurface infiltration bed under garden

downspouts, runoff can be designed to sheet flow off a pitched roof surface and onto a stabilized ground cover that is then directed toward a dry well via stormwater pipes or swales.

Dry wells discharge the stored runoff via infiltration into the surrounding soils. In the event that the dry well is overwhelmed in an intense storm event, an overflow mechanism (e.g., surcharge pipe, connection to larger infiltration area, etc.) will ensure that additional runoff is safely conveyed downstream.

Prefabricated Dry Wells

There are a variety of prefabricated, predominantly plastic subsurface storage chambers on the market today that can replace aggregate dry wells. Since these systems have significantly greater storage capacity than aggregate, space requirements are reduced and associated costs may be defrayed. If the following design guidelines are followed and infiltration is still encouraged, prefabricated chambers can prove just as effective as standard aggregate dry wells.

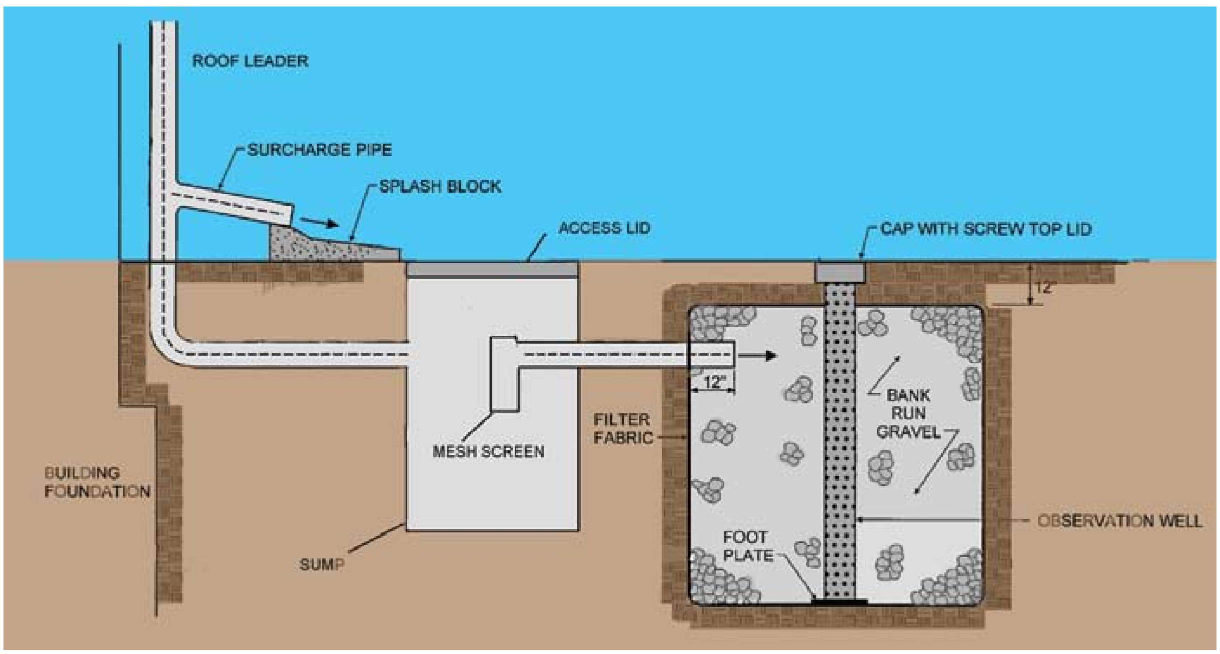

Figure 4 Cross Section of dry well with "sumped" catch basin for sediment pretreatment

Infiltration berm

Infiltration berms are linear vegetation features located along (i.e. parallel to) existing site contours in a moderately sloping area. They are built-up earthen embankments with sloping sides, which function to retain, slow down, or divert stormwater flows. Infiltration berms also have shallow depressions created by generally small earthen embankments that collect and temporarily store stormwater runoff, allowing it to infiltrate into the ground and recharge groundwater.

Infiltration berms can be constructed in various areas on the site, including:

Diversion berms

Diversion berms can be used to protect slopes from erosion and to slow runoff rate. Like swales, berms may divert concentrated discharge from a developed area away from the sloped area. Additionally, berms may be installed in series down the slope to retain flow and spread it out along multiple, level berms to discourage concentrated flow.

Diversion berms can also be used to direct stormwater flow in order to promote longer flow pathways, thus increasing the time of concentration. For example, berms can be installed such that vegetated stormwater flow pathways are allowed to “meander” so that stormwater travel time is increased.

Meadow/woodland infiltration berms

Woodland infiltration berms can be installed within existing wooded areas for additional stormwater management. Berms in wooded areas can even improve the health of existing vegetation, through enhanced groundwater recharge. Care should be taken during construction to ensure minimum disturbance to existing vegetation, especially tree roots.

Berms are also utilized for a variety of reasons independent of stormwater management, such as to add aesthetic value to a flat landscape, create a noise or wind barrier, separate land uses, screen undesirable views or to enhance or emphasize landscape designs. Berms are often used in conjunction with recreational features, such as pathways through woodlands. In summary, even when used for stormwater management, berms can be designed to serve multifunctional purposes and are easily incorporated into the landscape.

Design Considerations

The following general design considerations are for all BMPs utilizing infiltration. These include site conditions and constraints, as well as general design considerations. Specific design considerations for each BMP follow these same considerations.

Site conditions and constraints for all infiltration BMPs

- **Depth to seasonal high water table**. A four-foot clearance above the seasonally high water table is recommended. A two-foot clearance can be used, but may reduce the performance of the BMP. This reduces the likelihood that temporary groundwater mounding will affect the system, and allows sufficient distance of water movement through the soil to assure adequate pollutant removal. In special circumstances, filter media may be employed to remove pollutants if adequate soil layers do not exist.

- **Depth to bedrock**. A four-foot minimum depth to bedrock is recommended to assure adequate pollutant removal and infiltration. A two-foot depth can be used, but may reduce the performance of the BMP. In special circumstances, filter media may be employed to remove pollutants if adequate soil mantle does not exist.

- **Soil infiltration**. Soils underlying infiltration devices should have infiltration rates between 0.1 and 10 inches per hour, which in most development programs should result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible, but the surface area required could be large, and other volume reduction methods may be warranted. Undisturbed Hydrologic Soil Groups A, B, and C often fall within this range and cover most of the state. Type D soils may require the use of a double-walled underdrain.

Soils with rates in excess of six inches per hour may require an additional soil buffer (such as an organic layer over the bed bottom) if the Cation Exchange Capacity (CEC) is less than 10 and pollutant loading is expected to be significant. In carbonate soils, excessively rapid drainage may increase the risk of sinkhole formation, and some compaction or additional measures may be appropriate.

- **Setbacks**. Infiltration BMPs should be sited so that any risk to groundwater quality is minimized and they present no threat to sub-surface structures such as foundations and septic systems. (**Table 1**)

Setback from	Minimum Distance (feet)
Property Line	10
Building Foundation*	10
Private Well	50
Public Water Supply Well**	50
Septic System Drainfield***	100

Table 1 Setback Distances

* Minimum with slopes directed away from building. 100 feet up gradient from basement foundations.
** At least 200 feet from Type I or IIa wells, 75 feet from Type IIb and III wells
*** 50 feet for septic systems with a design flow of less than 1,000 gallons per day

General design considerations for all infiltration BMPs

- **Do not infiltrate in compacted fill**. Infiltration in native soil without prior fill or disturbance is preferred but not always possible**.** Areas that have experienced historic disturbance or fill are suitable for infiltration provided sufficient time has elapsed and the soil testing indicates the infiltration is feasible. In disturbed areas, it may be necessary to infiltrate at a depth that is beneath soils that have previously been compacted by construction methods or long periods of mowing, often 18 inches or more. If site grading requires placement of an infiltration BMP on fill, compaction should be minimal to prevent excess settlement. The infiltration capacity of the compacted fill should be measured in the field to ensure the design values used are valid.

- **A level infiltration area (one percent or less slope) is preferred**. Bed bottoms should always be graded into the existing soil mantle, with terracing as required to construct flat structures. Sloped bottoms tend to pool and concentrate water in small areas, reducing the overall rate of infiltration and longevity of the BMP. The longitudinal slope may range only from the preferred zero percent up to one percent, and that lateral slopes are held at zero percent. It is highly recommended that the maximum side slopes for an infiltration practice be 1:3 (V: H).

- **The soil mantle should be preserved for surface infiltration BMPs** and excavation should be minimized. Those soils that do not need to be disturbed for the building program should be left undisturbed. Macropores can provide a significant mechanism for water movement in surface infiltration systems, and the extent of macropores often decreases with depth. Maximizing the soil mantle also increases the pollutant removal capacity and reduces concerns about groundwater mounding. Therefore, excessive excavation for the construction of infiltration systems is strongly discouraged.

- **Isolate hot spot areas**. Site plans that include infiltration in hot spots need to be reviewed carefully. Hot spots are most often associated with some industrial uses and high traffic – gasoline stations, vehicle maintenance areas, and high intensity commercial uses (fast food restaurants, convenience stores, etc.). Infiltration may occur in areas of hot spots provided pretreatment is suitable to address concerns.

- **Utilize pretreatment**. Pretreatment should be utilized for most infiltration BMPs, especially for hot spots and areas that produce high sediment loading. Pretreatment devices that operate effectively in conjunction with infiltration include grass swales, vegetated filter strips, settling chambers, oil/grit separators, constructed wetlands, sediment sumps, and water quality inserts. Selection of pretreatment should be guided by the pollutants of greatest concern, site by site, depending upon the nature and extent of the land development under consideration. Selection of pretreatment techniques will vary depending upon whether the pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated.

- **The loading ratio of impervious area to bed bottom area must be considered**. One of the more common reasons for infiltration system failure is the design of a system that attempts to infiltrate a substantial volume of water in a very small area. Infiltration systems work best when the water is “spread out”. The loading ratio describes the ratio of imperious drainage area to infiltration area, or the ratio of total drainage area to infiltration area. In general, the following loading ratios are recommended (some situations, such as highly permeable soils, may allow for higher loading ratios):

    - Maximum impervious loading ratio of 5:1 relating impervious drainage area to infiltration area.
    - Maximum total loading ratio of 8:1 relating total drainage area to infiltration area.

- **The hydraulic head or depth of water should be limited**. The total effective depth of water within the infiltration BMP should generally not be greater than two feet to avoid excessive pressure and potential sealing of the bed bottom. Typically, the water depth is limited by the loading ratio and drawdown time and is not an issue.

- **Drawdown time must be considered**. In general, infiltration BMPs should be designed so that they completely empty within a 72-hour period in most situations (a 48-hour period is preferred).

- **All infiltration BMPs should be designed with a positive overflow** that discharges excess volume in a non-erosive manner, and allows for controlled discharge during extreme rainfall events or frozen bed conditions. Infiltration BMPs should never be closed systems dependent entirely upon infiltration in all storm frequency situations.

- **Geotextiles should be incorporated into the design as necessary**. Infiltration BMPs that are subject to soil movement into the stone medium or excessive sediment deposition must be constructed with suitably permeable non-woven geotextiles to prevent the movement of fines and sediment into the infiltration system. The designer is encouraged to err on the side of caution and use geotextiles as necessary within the BMP structure.

- **Aggregates used in construction should be washed**. In general, bank run material will contain fines that will wash off and clog the infiltration surface.

- **Infiltration utilizing vegetation**. Adequate soil cover (generally 12 to 18 inches) must be maintained above the infiltration bed to allow for a healthy vegetative cover. Vegetation over infiltration beds can be native grasses, meadow mix, or other low-growing, dense species (see Recommended Plant List for BMPs Appendix). These plants have longer roots than traditional grass and will likely benefit from the moisture in the infiltration bed, improving the growth of these plantings and, potentially increasing evapotranspiration.

- **Using underdrains in poor draining soils**. Double-walled underdrains can be used in infiltration BMPs where in situ soils are expected to cause ponding lasting longer than 48 hours. If used, underdrains are typically small diameter (6 to 12 inches) perforated pipes in a clean gravel trench wrapped in geotextile fabric (or in the storage/infiltration bed). Underdrains should have a flow capacity greater than the total planting soil infiltration rate and should have at least 18 inches of soil/gravel cover. They can daylight to the surface or connect to another stormwater system. A method to inspect and clean underdrains should be provided (via cleanouts, inlet, overflow structure, etc.)

Infiltration practices are prohibited in proximity to public water supply wells as discussed in the Post-Construction Stormwater Quality Chapter, Section F Step 5 of the Technical Standards.

- Low **berm height** (less than or equal to 24 inches) is recommended to encourage maximum infiltration and to prevent excessive ponding behind the berm. Greater heights may be used where berms are being used to divert flow or to create "meandering" or lengthened flow pathways. In these cases, stormwater is designed to flow adjacent to (parallel to), rather than over the crest of the berm. Generally, more berms of smaller size are preferable to fewer berms of larger size.

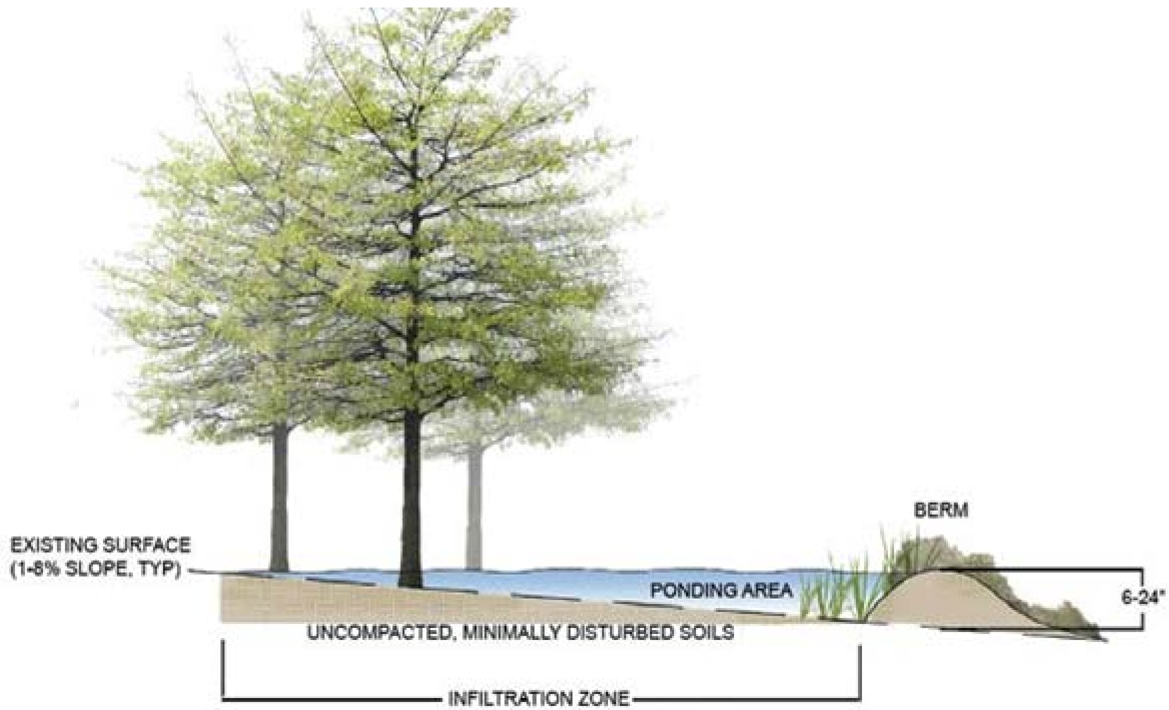

Figure 5 Typical Components of a Berm

- **Freeboard**. It is recommended that two feet of freeboard be provided from the 100-year flood elevation of the infiltration practice to the lowest basement floor elevation of residential, commercial, industrial, and institutional buildings located adjacent to the BMP, unless local requirements recommend or stipulate otherwise.

Additional design considerations for infiltration berms

- Sizing criteria (**Figure 5**) are dependent on berm function, location, and storage volume requirements.
- **Berm length** is dependent on functional need and site size. Berms installed along the contours should be level and located across the slope. Maximum length will depend on width of the slope.
- Infiltration berms should be constructed along (parallel to) contours at a **constant level elevation**.

- **Soil**. The top one foot of a berm needs to consist of high quality topsoil, with well-drained, stable fill material making up the remainder of the berm. A berm may also consist entirely of high quality topsoil, but this is the more expensive option.

The use of gravel is not recommended in the layers directly underneath the topsoil because of the tendency of the soil to wash through the gravel. In some cases, the use of clay may be required due to its cohesive qualities (especially where the berm height is high or relatively steeply sloped). However, well-compacted soil is usually sufficient provided that the angle of repose, the angle at which the soil will rest and not be subject to slope failure (discussed below), is adequate for the soil medium used.

- The **angle of repose** of any soil will vary with the texture, water content, compaction, and vegetative cover. Typical angles of repose are given below:
    - Non-compacted clay: 5 to 20 percent
    - Dry Sand: 33 percent
    - Loam: 35 to 40 percent
    - Compacted clay: 50 to 80 percent

- **Slope** The angle of repose for the soil used in the berm should determine the maximum slope of the berm with additional consideration being given to aesthetic, drainage, and maintenance needs. If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to avoid "scalping" by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 to 7:1 ratio. Other herbaceous plants which do not require mowing can tolerate slopes of 3:1, though this slope ratio may promote increased runoff rate and erosive conditions. Berm side slopes should never exceed a 2:1 ratio.

- **Plant materials**. It is important to consider the function and form of the berm when selecting plant materials. When using native trees and shrubs, plant them in a pattern that appears natural and accentuates the form of the berm. Consider native species from a rolling prairie or upland forest habitat. If turf will be combined with woody and herbaceous plants, the turf should be placed to allow for easy maneuverability while mowing. Low maintenance native plantings, such as trees and meadow plants, rather than turf and formal landscaping, are encouraged and can be found in Recommended Plant List for BMPs Appendix. Additionally, plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

- **Infiltration trench option**. Soil testing is required for infiltration berms that will utilize a subsurface infiltration trench. Infiltration trenches are not recommended in existing woodland areas, because excavation and installation of subsurface trenches could damage tree root systems. See the infiltration trench section for information on infiltration trench design.

- **Aesthetics**. To the extent possible, berms should reflect the surrounding landscape. Berms should be graded so that the top of the berm is smoothly convex and the toes of the berms are smoothly concave. Natural, asymmetrical berms are usually more effective and attractive than symmetrical berms, which tend to look more artificial. The crest of the berm should be located near one end of the berm rather than in the middle.

- **Pretreatment**. The small depression created by an infiltration berm can act as a sediment forebay prior to stormwater entering a down slope BMP, such as a bioretention basin, a subsurface infiltration bed, or another such facility. Sediment forebays must be in compliance with local Stormwater Management Ordinance and standard detailed drawing requirements.

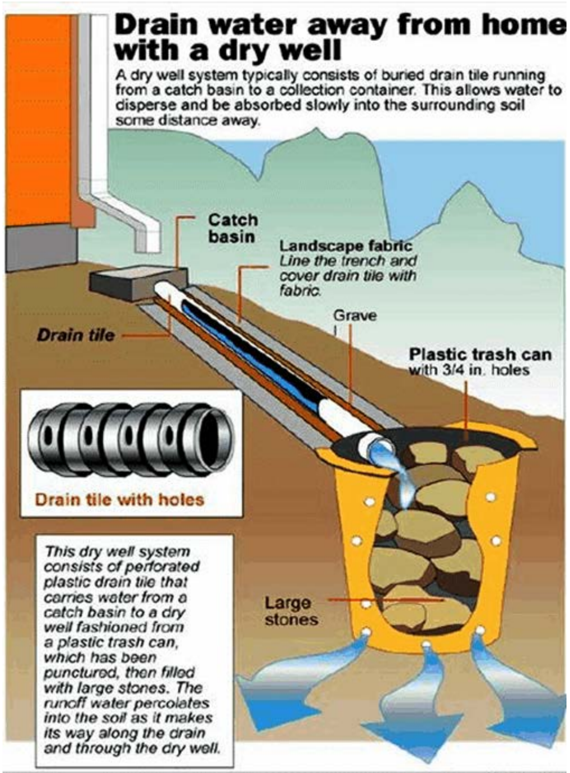

Figure 6 Residential dry well
Source - AP/Stan Kohler

Additional design considerations for dry wells

- Dry wells typically consist of 18 to 48 inches of clean washed, uniformly graded aggregate with 40 percent void capacity (AASHTO No. 3, or similar). Dry well aggregate is wrapped in a nonwoven geotextile, which provides separation between the aggregate and the surrounding soil. Typically, dry wells will be covered in at least 12 inches of soil or six inches of gravel or riverstone. An alternative form of dry well is a subsurface, prefabricated chamber, a number of which are currently available on the market.

- All dry wells must be able to convey system overflows to downstream drainage systems. System overflows can be incorporated either as surcharge (or overflow) pipes extending from roof leaders or via connections from the dry well itself.

- The design depth of a dry well should take into account frost depth to prevent frost heave.

- A removable filter with a screened bottom should be installed in the roof leader below the surcharge pipe in order to screen out leaves and other debris.

- Inspection and maintenance access to the dry well should be provided. Observation wells not only provide the necessary access to the dry well, but they also provide a conduit through which pumping of stored runoff can be accomplished in case of slowed infiltration.

- Though roofs are generally not a significant source of runoff pollution, they can still be a source of particulates and organic matter, as well as sediment and debris during construction. Measures such as roof gutter guards, roof leader clean-outs with sump, or an intermediate sump box can provide pretreatment for dry wells by minimizing the amount of sediment and other particulates that enter it.

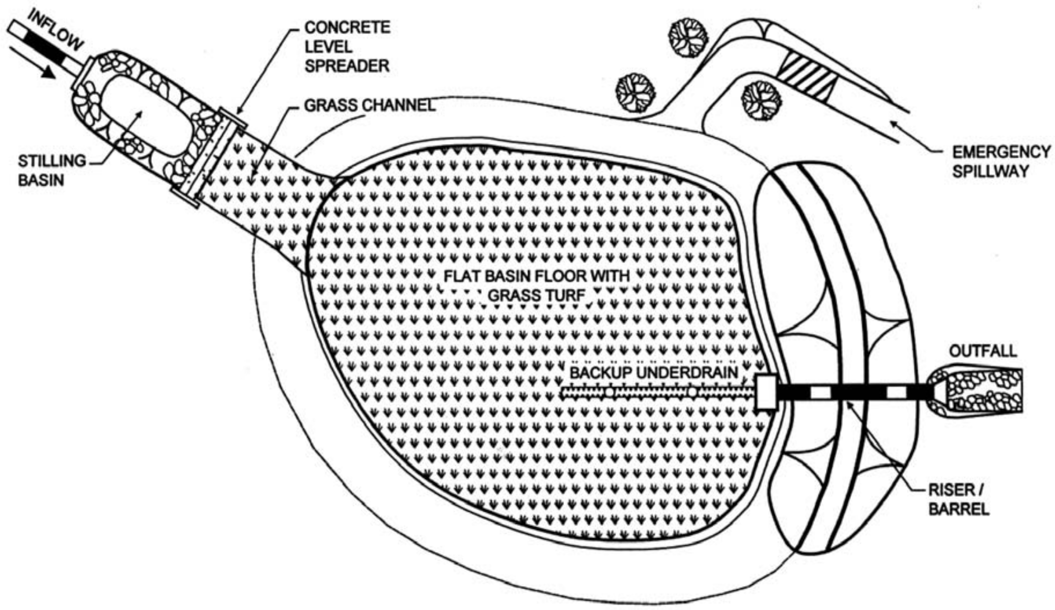

Figure 7 Infiltration Basin Sketch

Additional Design Considerations for Infiltration Basins

- Infiltration basins are typically used for drainage areas of 5 to 50 acres with land slopes that are less than 20 percent.

- A six-inch layer of sand must be placed on the bottom of an infiltration basin (**Figure 7**). This sand layer can intercept silt, sediment, and debris that could otherwise clog the top layer of the soil below the basin.

- An infiltration basin does not normally have a structural outlet to discharge runoff from the stormwater quality design storm. Instead, outflow from an infiltration basin is through the surrounding soil. An infiltration basin may also be combined with an extended detention basin to provide additional runoff storage for both stormwater quality and quantity management. A structural outlet or emergency spillway is provided for storms that exceed the design of the infiltration basin.

- The berms surrounding the basin should be compacted earth with a slope of not less than 3:1, and a top width of at least two feet.

- The overflow from the infiltration basin must be properly designed for anticipated flows. Large infiltration basins may require multiple outlet control devices to effectively allow for overflow water during the larger storms. Emergency overflow systems can be constructed to direct large storm overflows.

- The sediment pre-treatment structure should be designed to provide for access and maintenance.

- In some cases, basins may be constructed where impermeable soils on the surface are removed and where more permeable underlying soils are used for the basin bottom. Care should be taken in the excavation process to make sure that soil compaction does not occur.

- The inlets into the basin should have erosion protection.

- Use of a backup, double-walled underdrain or low-flow orifice may be considered in the event that the water in the basin does not drain within 72 hours.

lot and road runoff should never be directly discharged underground.

Additional design considerations for infiltration trenches

- The infiltration trench (**Figure 8)** is typically comprised of a section of uniformly graded aggregate, such as AASHTO No. 3, which ranges one to two inches in gradation. Depending on local aggregate availability, both larger and smaller size aggregate may be used. The critical requirements are that the aggregate be uniformly-graded, clean-washed, and contain at least 40 percent void space. The depth of the trench is a function of stormwater storage requirements, frost depth considerations, and site grading.
- Cleanouts, observation wells, or inlets must be installed at both ends of the infiltration trench and at appropriate intervals to allow access to the perforated pipe.
- When designed as part of a storm sewer system, a continuously perforated pipe that extends the length of the trench and has a positive flow connection may be included to allow high flows to be conveyed through the infiltration trench. Depending on size, these pipes may provide additional storage volume.

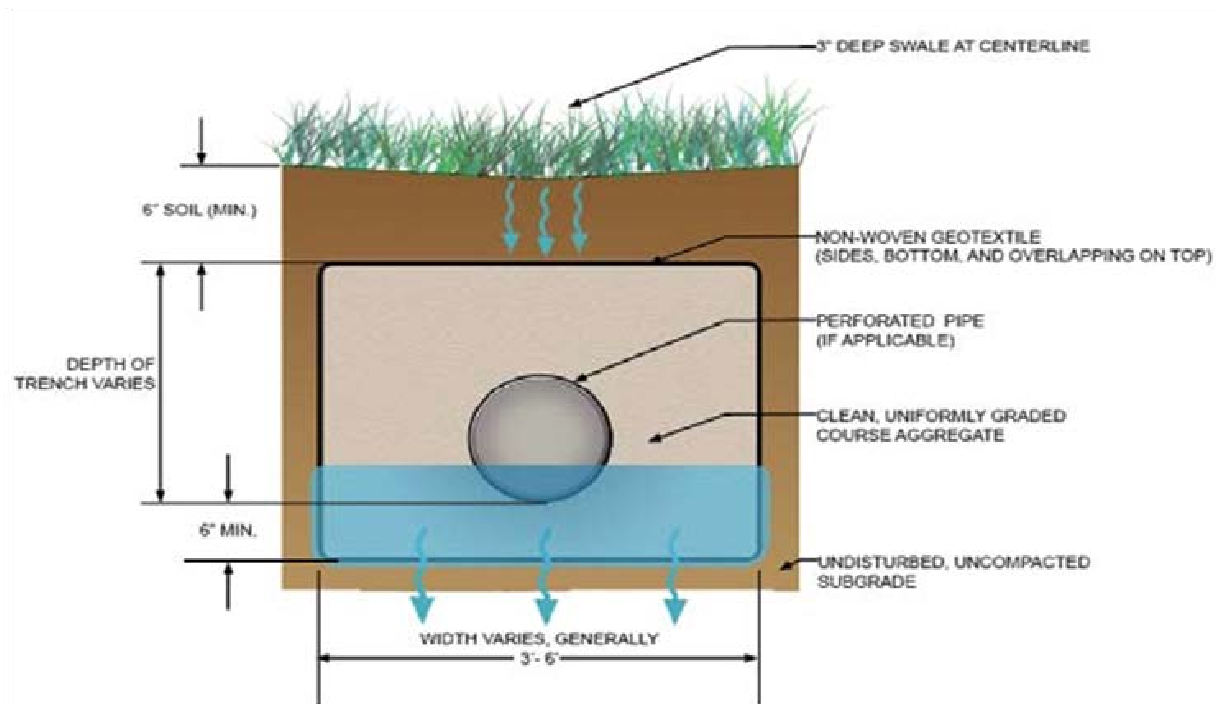

Figure 8 Infiltration trench cross section

- Water quality inlets or catch basins with sumps are required for all surface inlets to prevent clogging of the infiltration trench with sediment and debris. Parking lot and street runoff must be treated by vegetated filter strips, bioretention, or water quality inlets capable of removing oil and grease and similar pollutants. Untreated parking
- Trees may be planted over the infiltration trench provided that adequate soil media is provided above the trench (a minimum of three feet).
- While most infiltration trenches areas consist of an aggregate storage bed, alternative subsurface storage products may also be employed. These include a

variety of proprietary, interlocking plastic units that contain much greater storage capacity than aggregate, though at an increased cost.

Additional design considerations for subsurface infiltration beds

- The infiltration bed must be wrapped in nonwoven geotextile filter fabric to prevent migration of the subsoils into the stone voids (bottom, top, and sides).
- A water quality inlet or catch basin with sump is required for all surface inlets to avoid standing water for periods greater than 72 hours.
- Perforated pipes along the bottom of the bed can be used to evenly distribute runoff over the entire bed bottom. Continuously perforated pipes should connect structures (such as cleanouts and inlet boxes). Pipes should lay flat along the bed bottom to provide for uniform distribution of water. Depending on size, these pipes may provide additional storage volume.

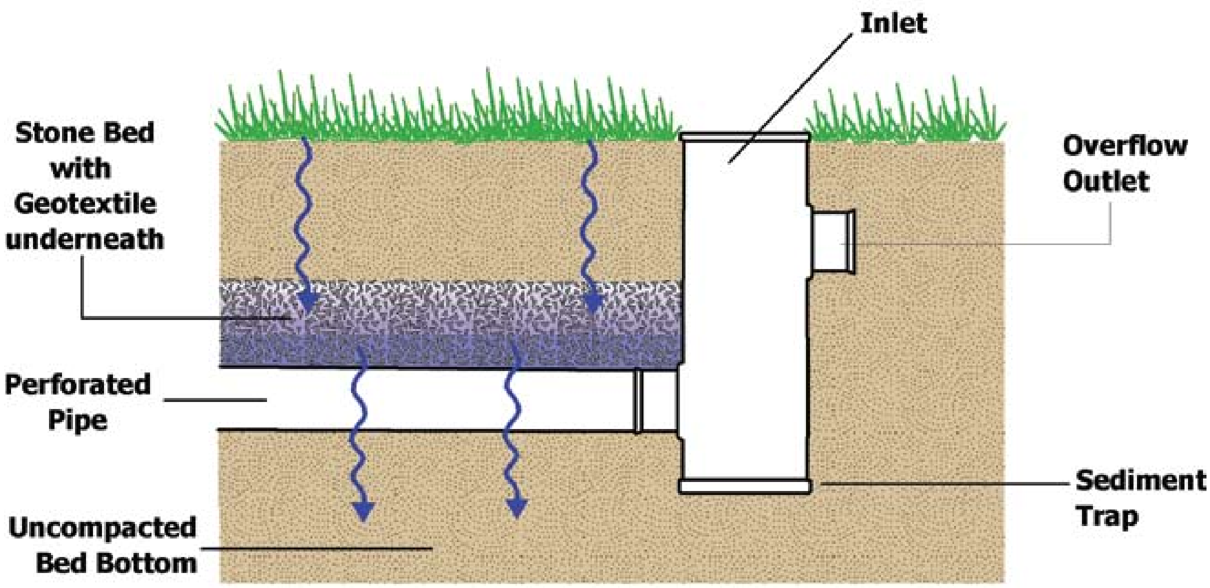

Figure 9 Schematic of subsurface infiltration bed cross section

- The subsurface infiltration bed (**Figure 9**) is typically comprised of a 12 to 36-inch section of aggregate, such as AASHTO No.3, which ranges from one to two inches in gradation. Depending on local aggregate availability, both larger and smaller size aggregate has been used. The critical requirements are that the aggregate be uniformly-graded, clean-washed, and contain at least 40 percent void space. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, and site grading. Infiltration beds are typically sized to mitigate the increased runoff volume from a two-year design storm.
- Cleanouts or inlets should be installed at a few locations within the bed at appropriate intervals to allow access to the perforated piping network and storage media.
- Grading of adjacent contributing areas should be mildly sloped between one percent and three percent to facilitate drainage.
- In areas with poorly-draining soils, subsurface infiltration areas may be designed to slowly discharge to adjacent wetlands or bioretention areas.

- The subsurface bed and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the mitigation of peak flow rates. In this manner, detention basins may be eliminated or significantly reduced in size.

- During construction, the excavated bed may serve as a temporary sediment basin or trap, which can reduce overall site disturbance. The bed should be excavated to at least one foot above the final bed bottom elevation for use as a temporary sediment trap or basin. Following construction and site stabilization, sediment should be removed and final grades established.

Incorporating a Safety Factor into Infiltration BMP Design

For the purposes of site suitability, areas with tested soil infiltration rates as low as 0.1 inches per hour may be used for infiltration BMPs. However, in the design of these BMPs and the sizing of the BMP, the designer should incorporate a safety factor. Safety factors between 1 (no adjustment) and 10 have been used in the design of stormwater infiltration systems, with a factor of two being used in most cases. Therefore a measured infiltration rate of 0.5 inches per hour should generally be considered as a rate of 0.25 inches per hour in design. See the Soil Infiltration Protocol Index in Appendix E for guidance on performing infiltration tests.

Modeling Infiltration Systems

As discussed in the Post-Construction Stormwater Management Chapter of Technical Standards, infiltration systems can be modeled similarly to traditional detention basins. The marked difference with modeling infiltration systems is the inclusion of the infiltration rate, which can be considered as another outlet. For modeling purposes, it is sometimes useful to develop infiltration rates that vary (based on the infiltration area provided as the system fills with runoff) for inclusion in the stage-storage-discharge table.

	Volume	Peak Rate	Water Quality
Infiltration Berms	Can be used to reduce the volume of runoff and provide infiltration in accordance with LID stormwater goals. The volume reduction potential of berms is a function of the storage provided (surface and subsurface, if applicable) and the infiltration that will occur.	Can be used at mitigating peak rates for larger storms through two mechanisms: providing storage for detention (and on-going infiltration) behind them and, in some cases, elongating the flow path through a site, thereby extending the time of concentration.	Can be expected to achieve pollutant removals between 30% - 70% and in the upper ranges especially for smaller storms.
Infiltration Basins	Provides an excellent means of capturing and infiltrating runoff. Provides runoff volume storage during storm events, while the undisturbed vegetated surface allows infiltration of runoff into the underlying soil mantle. Can be sized to meet the entire channel protection volume recommended by LID criteria or sized smaller and used in conjunction with other LID practices.	Provides effective management of peak rates to meet the LID design criteria. The basin acts as a storage reservoir during large storm events, even while runoff infiltrates. Outlet structures can be designed to manage peak rates with the use of weir and orifice controls and systems can be designed to manage peak rates for storms up to and including the 100-year storm.	Effective in reducing total suspended solids, nutrients, metals, and oil and grease. Both the vegetative surface and the underlying soils allow pollutant filtration. When designed to capture and infiltrate runoff volumes from small storm events, they provide very high pollutant reductions.
Infiltration Trenches	Provides an excellent means of capturing and infiltrating runoff from small storms. The trench provides runoff volume storage and infiltration during small storm events, while the perforated pipe allows runoff conveyance during large design storms or more extreme events.	Provides limited management of peak rates. The trench may provide more peak rate benefit for small frequent storms, rather than large design storms. Because infiltration trenches help to provide a decentralized approach to stormwater management, they may benefit peak rate mitigation by contributing to increased stormwater travel time.	Effective in reducing total suspended solids, metals, and oil and grease. They provide very high pollutant reductions when designed to capture the volume from small storms because there is little, if any, discharge of runoff carrying the highest pollutant loads. Provide limited treatment of dissolved pollutants, such as nitrates.
Dry Wells	Dry wells are typically designed to capture and infiltrate runoff volumes from small storm events from roof area.	Provides limited management of peak rates. Provides some peak rate benefit by reducing direct connections of impervious area to storm sewer collection systems, and by contributing to increased stormwater travel time.	Effective at capturing and infiltrating the water quality volume or “first flush”. Provides very high pollutant reductions because there is little, if any, discharge of “first flush” runoff, which carries the highest pollutant loads.
Subsurface Infiltration	Provides effective management of volume. A well-designed system is capable of infiltrating the majority of small frequent storms on an annual basis.	Can be designed to manage peak rates by utilizing the stormwater storage bed, including simple rate controls such as weirs and orifices in the overflow control structure. Capable of infiltrating the majority of small frequent storms, while managing peak rates for designs storms up to the 100-year frequency storm.	Very effective at reducing total suspended solids, phosphorus, metals, and oil and grease. Because many systems are designed to capture and infiltrate small, frequent storms, they provide effective water quality control by reducing pollutants associated with the “first-flush”.

Table 2 Stormwater Functions by Infiltration BMP Type

Stormwater Functions and Calculations

Infiltration practices can provide excellent benefits for managing volume and water quality protection. While some BMPs are better than others in managing peak rates, all infiltration BMPs provide some peak rate benefit by removing direct connections from impervious surfaces and increasing time of travel. **Table 2** provides a summary of the stormwater functions by BMP type.

Calculations for Infiltration BMPs

Infiltration area

The minimum infiltration area should be based on the following (according to the loading ratio):
Minimum Surface Infiltration Area = [Contributing impervious area] / 5[#]

\# - May be increased depending on soil infiltration capacity (e.g., where soils are Type A or rapidly draining). For carbonate, geologic areas may be decreased to three.

This actual infiltration area (**Table 3**) should be greater than the minimum infiltration area.

Protecting Groundwater Quality

The protection of groundwater quality is of utmost importance in any Indiana watershed. The potential to contaminate groundwater by infiltrating stormwater in properly designed and constructed BMPs with proper pretreatment is low.

Numerous studies have shown that stormwater infiltration BMPs have a minor risk of contaminating either groundwater or soil. The U.S. Environmental Protection Agency summarized in "Potential Groundwater Contamination from Intentional and Non-intentional Stormwater Infiltration" (Pitt et al., 1994) the potential of pollutants to contaminate groundwater as either low, low/moderate, moderate, or high. Of the 25 physical pollutants listed, one has a "high" potential (chloride), and two have "moderate" potential (fluoranthene and pyrene) for polluting groundwater through the use of shallow infiltration systems with some sediment pretreatment.

While chloride can be found in significant quantities due to winter salting, relatively high concentrations are generally safe for both humans and aquatic biota. Pentachlorophenol, cadmium, zinc, chromium, lead, and all the pesticides listed are classified as having a "low" contamination potential. Even nitrate, which is soluble and mobile, is only given a "low/moderate" potential.

BMP	Infiltration Area Definition
Infiltration Berms	Total Infiltration Area (Ponding Area) = Length of Berm * Average Width of ponding behind berm.
Infiltration Basin	The Infiltration Area is the bottom area of the basin. This is the area to be considered when evaluating the Loading Ratio to the Infiltration basin.
Infiltration Trench	The Infiltration Area is the bottom area of the trench. This is the area to be considered when evaluating the Loading Rate to the Infiltration basin. [Length of Trench] x [Width of Trench] = Infiltration Area (Bottom Area) Some runoff reduction recognition can be taken for the side area that is frequently inundated, as appropriate.
Dry Well	A dry well may consider both bottom and side (lateral) infiltration according to design.
Subsurface Infiltration	The Infiltration Area is the bottom area of the bed. Some runoff reduction recognition can be taken for the side area that is frequently inundated as appropriate.

Table 3 Definition of Infiltration Area for Infiltration BMPs

Volume reduction

Infiltration BMPs can be used to reduce the volume of runoff and provide infiltration in accordance with LID stormwater goals. The volume reduction potential is a function of the storage provided (surface and subsurface, if applicable) and the infiltration that will occur. If a perforated pipe or double-walled underdrain is used in the design that discharges directly to surface water, the volume of water discharged must be subtracted from the volume reduction calculation.

Total Volume Reduced = Surface Storage Volume (if applicable) + Subsurface Volume (if applicable) + Infiltration Volume

Where,

Surface storage volume (ft^3) = Average bed area * (ft^2) x maximum design water depth (ft)

Subsurface storage/Infiltration bed volume (ft^3) = Infiltration area (ft^2) * Depth of underdrain material (ft) * Void ratio of storage material

**Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.*

Estimated Infiltration Volume (CF) = [Bed bottom area (ft^2)] * [Infiltration design rate (in/hr)] * [Infiltration period# (hr)] / 12 inches/ft.

 # - Infiltration Period is the time during the storm event when bed is receiving runoff and capable of infiltration at the design rate (typically 6 to 12 hours).

Peak rate mitigation

The amount of peak rate control provided by infiltration practices is dependent on the cumulative runoff volume removed by all the infiltration practices applied to a site. Where sufficient infiltration is provided to control the runoff volume from any size storm, the corresponding peak runoff rate will also be restored and the peak runoff rate from larger, less frequent storms will be reduced. Where possible, reducing peak rate of runoff through volume control is generally more effective than fixed rate controls.

Some infiltration BMPs (e.g., infiltration basins) can manage peak rates better than others (e.g., infiltration berms). However, all infiltration BMPs provide some peak rate benefit (e.g., by removing direct connections from impervious surfaces and increasing time of travel).

Water quality improvement

Infiltration practices are effective in reducing pollutants such as total suspended solids, nutrients, metals, oil and grease. The vegetative surface and the underlying soils allow pollutant filtration and studies have shown that pollutants typically are bound to the soils and do not migrate deeply below the surface (i.e. greater than 30-inches). Infiltration practices should be used as part of a treatment train when capturing runoff from storm-water hot spots, such as industrial parking lots, due to the increased level of pollutants. Typical ranges of pollutant reduction efficiencies for infiltration practices are based on available literature data and listed below:

TSS – 75 to 90 percent
TP – 60 to 75 percent
TN – 55 to 70 percent
NO_3 – 30 percent

Construction Guidelines

The following guidelines apply for all infiltration BMPs.

- **Do not compact soil infiltration beds during construction**. Prohibit all heavy equipment from the infiltration area and absolutely minimize all other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as low ground pressure (maximum four pounds per square inch) tracked vehicles. Areas for Infiltration should be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

- Protect the infiltration area from sediment by ensuring erosion and sediment control practices are implemented until the surrounding site is completely stabilized. Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Where geotextile is used as a bed bottom liner, this should be extended several feet beyond the bed and folded over the edge to protect from sediment wash into the bed during construction, and then trimmed.

- Runoff from construction areas should never be allowed to drain to infiltration BMPs. This can usually be accomplished by diversion berms and immediate vegetative stabilization. The infiltration area may be used as a temporary sediment trap or basin during earlier stages of construction. However, if an infiltration area is also to be utilized as a temporary sediment basin, excavation should be limited to within one foot of the final bottom invert of the infiltration BMP to prevent clogging and compacting the soil horizon, and final grade removed when the contributing site is fully stabilized.

- All infiltration BMPs should be finalized at the end of the construction process, when upstream soil areas have a dense vegetative cover. In addition, do not remove inlet protection or other erosion and sediment control measures until site is fully stabilized. Any sediment which enters inlets during construction is to be removed within 24 hours.

- Provide thorough construction oversight. Long-term performance of infiltration BMPs is dependent on the care taken during construction. Generally, plans and specifications must be followed precisely. The designer is encouraged to meet with the contractor to review the plans and construction sequence prior to construction, and to inspect the construction at regular intervals and prior to final acceptance of the BMP.

- Provide quality control of materials. As with all BMPs, the final product is only as good as the materials and workmanship that went into it. The designer is encouraged to review and approve materials and workmanship, especially as related to aggregates, geotextiles, soil and topsoil, and vegetative materials.

Additional Construction Guidelines for Infiltration Berms

The following is a typical construction sequence for an infiltration berm without a subsurface infiltration trench, though alterations will be necessary depending on design variations.

- Lightly scarify (by hand) the soil in the area of the proposed berm before delivering soil to site (if required). Heavy equipment should not be used within the berm area.

- Bring in fill material to make up the major portion of the berm (as necessary) as soon as subgrade preparation is complete in order to avoid accumulation of debris. Soil should be added in eight-inch lifts and compacted after each addition according to design specifications. The slope and shape of the berm should be graded out as soil is added.

- Protect the surface ponding area at the base of the berm from compaction. If compaction of this area does occur, scarify soil to a depth of at least 8 inches.

- After allowing for settlement, complete final grading within two inches of proposed design elevations. Tamp soil down lightly and smooth sides of the berm. The crest and base of the berm should be level along the contour.

- Seed and plant berm with turf, meadow plants, shrubs or trees, as desired. Water vegetation at the end of each day for two weeks after planting is completed. (Recommended Plant List for BMPs Appendix).

- Mulch planted and disturbed areas with compost to prevent erosion while plants become established.

Additional Construction Guidelines for Subsurface Infiltration

- Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material should be removed with light equipment and the underlying soils scarified to a minimum depth of six inches with a York rake (or equivalent) and light tractor. All fine grading should be done by hand. All bed bottoms are to be at level grade.

- Earthen berms (if used) between infiltration beds should be left in place during excavation.

- Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation and installation of structures. Adjacent strips of geotextile should overlap a minimum of 18 inches, and should also be secured at least four feet outside of the bed to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until storage media is placed in the bed.

- Clean washed, uniformly graded aggregate should be placed in the bed in maximum eight-inch lifts. Each layer should be lightly compacted, with construction equipment kept off the bed bottom as much as possible.

- Once bed aggregate has been installed, geotextile can be folded over the top of the aggregate bed. Additional geotextile should be placed as needed to provide a minimum overlap of 18 inches between adjacent geotextile strips.

- Place approved engineered soil media over infiltration bed in maximum six-inch lifts.

- Seed and stabilize topsoil.

Additional Construction Guidelines for Infiltration Trenches

- Excavate infiltration trench bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade.

- Place nonwoven geotextile along bottom and sides of trench. Nonwoven geotextile rolls should overlap by a minimum of 16 inches within the trench. Fold back and secure excess geotextile during stone placement.

- Install upstream and downstream control structures, cleanouts, observation wells, etc.

- Place uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.

- Install continuously perforated pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.

- Fold and secure nonwoven geotextile over infiltration trench, with minimum overlap of 16 inches.

- If vegetated, place a minimum six-inch lift of approved topsoil over infiltration trench, as indicated on plans.

- Seed and stabilize topsoil.

Additional Construction Guidelines for Infiltration Basins

- If necessary, excavate infiltration basin bottom to provide a level and uncompacted subgrade free from rocks and debris. Never compact subgrade.

- Install outlet control structures.

- Seed and stabilize topsoil (Planting with native species is preferred).

Causes of Infiltration BMP Failure

With respect to stormwater infiltration BMPs, the result of “failure” is a reduction in the volume of runoff anticipated or the discharge of stormwater with excessive levels of some pollutants. Where the system includes built structures, such as porous pavements, failure may include loss of structural integrity for the wearing surface, whereas the infiltration function may continue uncompromised. For infiltration systems with vegetated surfaces, such as play fields or rain gardens, failure may include the inability so support surface vegetation, caused by too much or too little water.

The primary causes of reduced performances are:

- Poor construction techniques, especially soil compaction/smearing, which results in significantly reduced infiltration rates.
- A lack of site soil stabilization prior to the BMP receiving runoff, which greatly increases the potential for sediment clogging from contiguous land surfaces.
- Inadequate pretreatment, especially of sediment-laden runoff, which can cause a gradual reduction of infiltration rates.
- Lack of proper maintenance (erosion repair, re-vegetation, removal of detritus, catch basin cleaning, vacuuming of pervious pavement, etc.), which can reduce the longevity of infiltration BMPs.
- Inadequate design
- Inappropriate use of geotextile

Infiltration systems should always be designed such that failure of the infiltration component does not completely eliminate the peak rate attenuation capability of the BMP. Because infiltration BMPs are designed to infiltrate small, frequent storms, the loss or reduction of this capability may not significantly impact the storage and peak rate mitigation of the BMP during extreme events.

Additional Construction Guidelines for Dry Wells

- Excavate dry well bottom to a uniform, level uncompacted subgrade, free from rocks and debris. Do NOT compact subgrade. To the greatest extent possible, excavation should be performed with the lightest practical equipment. Excavation equipment should be placed outside the limits of the dry well.
- Completely wrap dry well with nonwoven geotextile. If sediment and/or debris have accumulated in dry well bottom, remove prior to geotextile placement. Geotextile rolls should overlap by a minimum of 18-24 inches within the trench. Fold back and secure excess geotextile during stone placement.
- Install continuously perforated pipe, observation wells, and all other dry well structures. Connect roof leaders to structures as indicated on plans.
- Place uniformly graded, clean-washed aggregate in 6-inch lifts, between lifts.
- Fold and secure nonwoven geotextile over trench, with minimum overlap of 12 inches.
- Place 12-inch lift of approved topsoil over trench, as indicated on plans.
- Seed and stabilize topsoil.
- Connect surcharge pipe to roof leader and position over splashboard.

Maintenance

There are a few general maintenance practices that should be followed for all infiltration BMPs. These include:

- All catch basins and inlets should be inspected and cleaned at least twice per year.

- The overlying vegetation of subsurface infiltration features should be maintained in good condition, and any bare spots re-vegetated as soon as possible.

- Vehicular access on subsurface infiltration areas should be prohibited (unless designed to allow vehicles), and care should be taken to avoid excessive compaction by mowers.

Additional Maintenance Information for Infiltration Berms

Infiltration berms have low to moderate maintenance requirements, depending on the design. Unless otherwise noted, the following maintenance actions are recommended on an as-needed basis.

Infiltration berms

- Regularly inspect to ensure they are infiltrating; monitor drawdown time after major storm events (total drawdown of the system should not exceed 72 hours; surface drawdown should not exceed 48 hours).

- Inspect any structural components, such as inlet structures, to ensure proper functionality

- If planted in turf grass, maintain by mowing (maintain two to four-inch height); other vegetation will require less maintenance; trees and shrubs may require annual mulching, while meadow planting requires annual mowing and clippings removal

- Avoid running heavy equipment over the infiltration area at the base of the berms; the crest of the berm may be used as access for heavy equipment when necessary to limit disturbance.

- Do not apply pesticides or fertilizers in and around infiltration structures

- Routinely remove accumulated trash and debris

- Remove invasive plants as needed

- Inspect for signs of flow channelization and/or erosion; restore level spreading immediately after deficiencies are observed (monthly)

Diversion berms

- Regularly inspect for erosion or other failures (monthly)

- Regularly inspect structural components to ensure functionality

- Maintain turf grass and other vegetation by mowing and re-mulching

- Do not apply pesticides or fertilizers where stormwater will be conveyed

- Remove invasive plants as needed

- Routinely remove accumulated trash and debris

Additional Maintenance Information for Infiltration Basins

- Inspect the basin after major storm events and make sure that runoff drains down within 72 hours. Mosquitoes should not be a problem if the water drains in 72 hours. Mosquitoes require a considerably long breeding period with relatively static water levels.

- Inspect for accumulation of sediment, damage to outlet control structures, erosion control measures, signs of water contamination/spills, and slope stability in the berms.

- Mow only as appropriate for vegetative cover species.

- Remove accumulated sediment from the sediment pretreatment device/forebay as needed. Inspect pretreatment forebay at least one time per year.

- If the infiltration basin bottom becomes clogged, scrape bottom and remove sediment and restore original cross section. Properly dispose of sediment.

Additional Maintenance Information for Dry Wells

- Inspect dry wells at least four times a year, as well as after every storm exceeding one inch.
- Remove sediment, debris/trash, and any other waste material from the dry well and dispose of at a suitable disposal/recycling site and in compliance with local, state, and federal waste regulations.
- Evaluate the drain-down time of the dry well to ensure the maximum time of 72 hours is not being exceeded. If drain down time exceeds the maximum, drain the dry well via pumping and clean out perforated piping, if included. If slow drainage persists, the system may need replacing.
- Regularly clean out gutters and ensure proper connections which will facilitate the effectiveness of the dry well.
- Replace filter screen that intercepts roof runoff as necessary.
- If an intermediate sump box exists, clean it out at least once per year.

Winter Considerations

Most infiltration practices are typically located below the frost line and continue to function effectively throughout the winter. It is imperative to prevent salt, sand, cinder, and any other deicers from clogging the surface area of infiltration practices by avoiding piling snow in these areas. Sand and cinder deicers could clog infiltration devices and soluble deicers, such as salt, can damage the health of vegetation.

Cost

The construction cost of many infiltration BMPs can vary greatly depending on the configuration, location, site conditions, etc. Following is a summary of both construction and maintenance costs. This information should be strictly as guidance. More detailed cost information should be discerned for the specific site before assessing the applicability of the BMP.

	Construction Costs	Maintenance Costs
Dry well*	$4-9/ft^3$	5-10% of capital costs
Infiltration basin	Varies depending on excavation, plantings, and pipe configuration.	Disposal costs
Infiltration trench**	$20-30/ ft^3$	5-10% of capital costs
Subsurface infiltration bed	$13/ ft^3$	

Table 4 Summary of construction and maintenance costs for infiltration BMPs
**2003 dollars.*
***City of Portland. 2006 dollars.*

Designer/Reviewer Checklist for Infiltration Berms

ITEM	Page No.	YES	NO	N/A	NOTES
Was the Soil Infiltration Testing Protocol followed?*	--				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured? ➢ *Min. infiltration rate:* ***0.1 in/hr*** ➢ *Max. infiltration rate:* ***10in/hr***	8				
Was the Infiltration BMP followed?	--				
Two-foot separation from bedrock/SHWT?	2,8				
Soil permeability acceptable?	8				
Natural, uncompacted soils?	9				
Excavation in berm areas minimized?	9				
Loading ratio considered? ➢ *Max. impervious drainage area loading ratio –* ***5:1*** ➢ *Max. total drainage area loading ratio –* ***8:1*** ➢ *Max. drainage area:* ***5 acres***	10				
Drawdown time less than 72 hours?	10				
Erosion and Sedimentation control?	--				
Feasible construction process and sequence?	20				
Entering flow velocities non-erosive?	--				
Berm height 6 to 24 inches?	11				
Berm designed for stability (temporary and permanent)?	--				
Acceptable berm side slopes? ➢ *Max. side slopes:* ***2:1 (H:V)***	12				
Are berm materials resistant to erosion?	--				
Located level, along contour?	11				
Acceptable soil for plants specified?	11				
Appropriate plants selected?	10				
Maintenance accounted for and plan provided?	23				

➢ *Denotes Minimum Design Considerations*

* *In general, the protocol should be followed as much as possible (although there is more flexibility for berms than for other BMPs such as pervious pavement and subsurface infiltration that rely almost entirely on infiltration).*

Designer/Reviewer Checklist for Infiltration Trenches, Infiltration Basins, Dry Wells, and Subsurface Infiltration Beds

ITEM	Page No.	YES	NO	N/A	NOTES
Was the Soil Infiltration Testing Protocol followed?	--				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured? ➢ *Min. infiltration rate:* ***0.1 in/hr*** ➢ *Max. infiltration rate:* ***10in/hr***	8				
Was the Infiltration BMP followed?	--				
Two-foot separation between the bed bottom and bedrock/ SHWT?	2,8				
Soil permeability acceptable?	8				
If not, appropriate underdrain provided?	--				
Adequate separations from wells, structures, etc.? ➢ *Minimum Setback Distances:* o *Property Line –* ***10 feet*** o *Building Foundation –* ***10 feet*** o *Private Well –* ***50 feet*** o *Public Water Supply Well –* ***50 feet*** o *Septic System Drainfield –* ***100 feet***	9				
Natural, uncompacted soils?	9				
Level infiltration area (e.g., trench bottom, bed bottom)?	9				
Excavation in infiltration area minimized?	9				
Hotspots/pretreatment considered?	9				
Loading ratio below 5:1? ➢ *Max. impervious drainage area loading ratio –* ***5:1*** ➢ *Max. total drainage area loading ratio –* ***8:1*** ➢ *Max. drainage area:* o *Dry Well –* ***1 acre*** o *Infiltration Basin –* ***10 acres*** o *Infiltration Trench –* ***2 acres*** o *Subsurface Infiltration Bed –* ***5 acres***	10				
Storage depth limited to two feet?	10				
Drawdown time less than 72 hours?	10,24				
Positive overflow from system?	2,7, 10,12				
Erosion and sedimentation control?	14,19, 20				
Feasible construction process and sequence?	21,22				
Geotextile specified?	10,12				

(continued on next page)

ITEM	Page No.	YES	NO	N/A	NOTES
Pretreatment provided?	4,9				
Clean, washed, open-graded aggregate specified?	10,12, 15				
Stable inflows provided (infiltration basin)?	--				
Appropriate perforated pipe, if applicable?	--				
Appropriate plants selected, if applicable?	10				
Observation well/clean out provided, if applicable?	13,15				
Maintenance accounted for and plan provided?	22-24				
Additional Design Considerations ➢ *Infiltration Basins* o *Berms – Min. 3:1 slope; Min. top width – 2 feet* ➢ *Infiltration Trenches* o *Soil media for tree planting – Min. of 3 feet*	--				

➢ Denotes Minimum Design Considerations

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BMP Fact Sheet

LEVEL SPREADERS

Level spreaders promote infiltration and improve water quality by evenly distributing flows over a stabilized, vegetated surface. This allows for better infiltration and treatment. There are several different types of level spreaders. Examples include concrete sills, earthen berms, and level perforated pipes.

Figure 1 Level spreader, Charlotte, NC (NC State University)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	No	Peak Rate	Low
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Low
Highway/Road	Yes	TP	Low
Recreational	Yes	NO_3	Low
		Temperature	Low

Additional Considerations	
Cost	Low
Maintenance	Low
Winter Performance	High

Variations (optional)

- Inflow
- Outflow

Key Design Features

- Ultimate outlet from structural BMPs
- Roof downspout connections (roof area > 500 ft^2)
- Inlet connections (impervious area > 500 ft^2)
- Inflow to structural BMP, such as a filter strip, infiltration basin, or vegetated swale

Site Factors

- Water table to bedrock depth: N/A
- Soils: Permeability not critical but should be considered for erodibility
- Slope: 1 to 8 percent max
- Potential hotspots: Yes
- Maximum drainage area: Varies (five acres maximum)

Benefits

- Low Cost
- Wide applicability
- Ability to work with other BMPs in a treatment train
- Avoids concentrated dischargers and their associated potential erosion

Limitations

- Low stormwater benefits by itself
- Careful design and construction required to function properly

Description and Function

Level spreaders are designed to disperse concentrated stormwater flows and are often used with other BMPs over a wide enough area to prevent erosion. Erosion can undermine a BMP, and can be a significant source of sediment pollution to streams and other natural water bodies. By dispersing flows, level spreaders assist vegetated BMPs in pollutant removal via filtration, infiltration, absorption, adsorption, and volatilization. Level spreaders also reduce the impact of a stormwater outlet to a receiving water body.

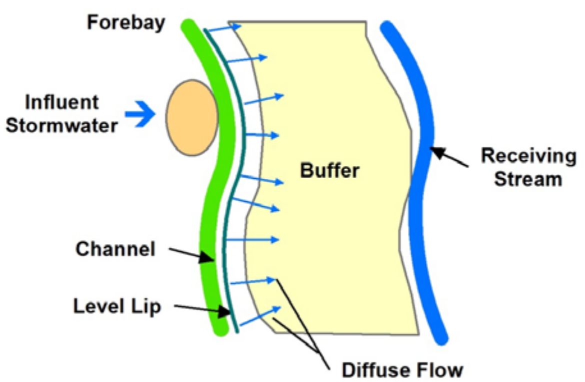

Figure 2 Level spreader located between a sediment forebay and a buffer
Source: NCSU-BAE

Variations

Inflow

Inflow level spreaders are meant to evenly distribute flow entering into another structural BMP, such as a filter strip, infiltration basin, or vegetated swale. Examples of this type of level spreader include concrete sills and earthen berms.

Outflow

Outflow level spreaders are intended to reduce the erosive force of high flows while at the same time enhancing natural infiltration opportunities. Examples of this second type include earthen berms and a level, perforated pipe in a shallow aggregate trench (**Figure 3**). In this example, the flow is from the left (from an outlet control device from another BMP) and flow reaches the spreader via the solid pipe.

Applications

Level spreaders can be used in a variety of applications, from residential areas to highway/road projects. The primary requirement is that there must be adequate area with an acceptable slope to receive the outflow from the spreader. In ultra-urban settings, there is typically not adequate space for level spreaders.

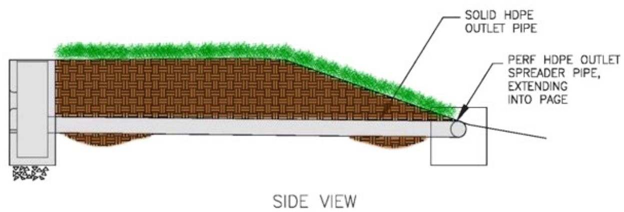

Figure 3 A level spreader with a perforated pipe

Figure 4, a close-up of Figure 3, shows an outlet pipe from an upstream BMP that serves as an inflow to the level spreader.

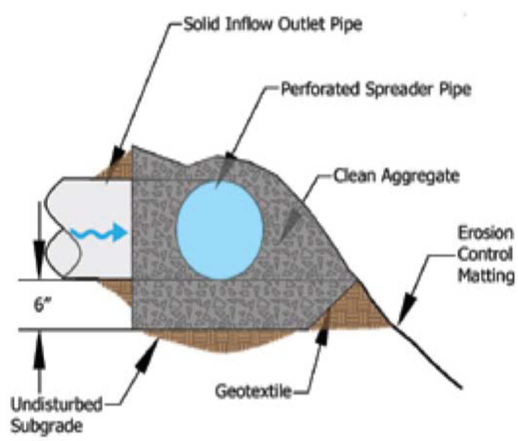

Figure 4 Level spreader with inflow pipe

Design Considerations

Level spreaders are considered a permanent part of a site's stormwater management system. Therefore, uphill development should be stabilized before any dispersing flow techniques are installed. If the level spreader is used as an erosion and sedimentation control measure, it must be reconfigured (flush perforated pipe, clean out all sediment) to its original state before use as a permanent stormwater feature.

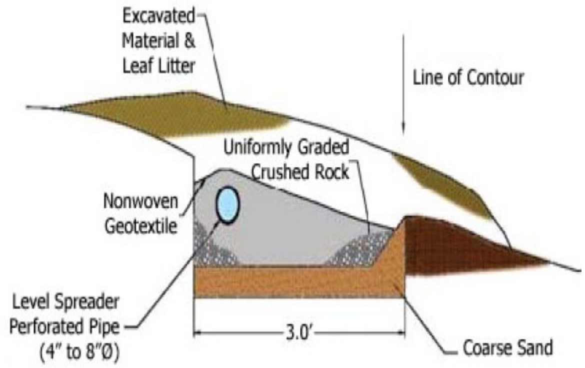

Figure 5 Level spreader with geotextile surrounding the aggregate helping to create a sloped area

All contributing stormwater elements (infiltration beds, inlets, outlet control structures, pipes, etc) should be installed first.

1. Provide as many outfalls as possible and avoid concentrating stormwater. This can reduce or even eliminate the need for engineered devices to provide even distribution of flow.

2. Level spreaders are not applicable in areas with easily erodible soils and/or little vegetation. The slope below the level spreader should be at a maximum eight percent in the direction of flow to discourage channelization. More gentle slopes (e.g., as low as one percent) are also acceptable.

3. The minimum length of flow after the level spreader (of the receiving area) should be 15 feet.

4. For design considerations of earthen berm level spreaders, refer to the Infiltration BMP.

5. Level spreaders should not be constructed in uncompacted fill. Undisturbed virgin soil and compacted fill is much more resistant to erosion and settlement than uncompacted fill.

6. Most variations of level spreaders should not be used alone for sediment removal. Significant sediment deposits in a level spreader will render it ineffective. A level spreader may be protected by adding a forebay to remove sediment from the influent. This can also make sediment cleanout easier.

7. Perforated pipe used in a level spreader may range in size from 4-12 inches in diameter. The pipe is typically laid in an aggregate envelope, the thickness of which is left to the discretion of the engineer. A deeper trench will provide additional volume reduction and should be included in such calculations (see Infiltration BMP). A layer of nonwoven geotextile filter fabric separates the aggregate from the adjacent soil layers, preventing migration of fines into the trench.

8. The length of level spreaders is primarily a function of the calculated influent flow rate. The level spreader should be long enough to freely discharge the desired flow rate. At a minimum, the desired flow rate should be that resulting from a 10-year design storm. This flow rate should be safely diffused without the threat of failure (i.e., creation of erosion, gullies, or rills). Diffusion of the storms greater than the 10-year storm is possible only if space permits. Generally, level spreaders should have a minimum length of 10 feet and a maximum length of 200 feet.

9. Conventional level spreaders designed to diffuse all flow rates should be sized based on the following:

   - For grass or thick ground cover vegetation:
     - 13 linear feet of level spreader for every one cubic feet per second (cfs) of flow
     - Slopes of eight percent or less from level spreader to toe of slope

   - For forested areas with little or no ground cover vegetation:
     - 100 linear feet of level spreader for every one cfs of flow
     - Slopes of six percent or less from level spreader to toe of slope

For slopes up to 15 percent for forested areas and grass or thick ground cover, level spreaders may be installed in series. The above recommended lengths should be followed.

10. The length of a perforated pipe level spreader may be further refined by determining the discharge per linear foot of pipe. A level spreader pipe should safely discharge in a distributed manner at the same rate of inflow, or less. If the number of perforations per linear foot (based on pipe diameter) and average head above the perforations are known, then the flow can be determined by the following equation:

$$L = Q_P / Q_L$$

Where:

L = length of level spreader pipe (ft.)
Q_P = design inflow for level spreader (cfs)
Q_L = level spreader discharge per length (cfs/ft)

AND

$$Q_L = Q_O * N$$

Where:

Q_L = level spreader discharge per length (cfs/ft)
Q_O = perforation discharge rate (cfs)
N = number of perforations per length of pipe, provided by manufacturer based on pipe diameter (Number/ft)

AND

$$Q_O = C_d * A * \sqrt{2gH}$$

Where:

Q_O = perforation discharge rate (cfs)
C_d = Coefficient of discharge (typically 0.60)
A = Cross sectional area of one perforation (ft^2)
g = acceleration due to gravity, 32.2 ft./sec^2
H = head, average height of water above perforation (ft.) (provided by manufacturer)

11. Flows may bypass a level spreader in a variety of ways, including an overflow structure or upturned ends of pipe. Cleanouts/overflow structures with open grates can also be installed along longer lengths of perforated pipe. Bypass may be used to protect the level spreader from flows above a particular design storm.

12. Erosion control matting, compost blanketing, or riprap on top of filter fabric are recommended immediately downhill and along the entire length of the level spreader, particularly in areas that are unstable or have been recently disturbed by construction activities. Generally, low flows that are diffused by a level spreader do not require additional stabilization on an already stabilized and vegetated slope.

Stormwater Functions and Calculations

Volume reduction

In general, level spreaders do not substantially reduce runoff volume. However, if level spreaders are designed similarly to infiltration trenches, a volume reduction can be achieved. Furthermore, for outflow level spreaders, the amount of volume reduction will depend on the length of level spreader, the density of receiving vegetation, the downhill length and slope, the soil type of the receiving area, and the design runoff. Large areas with heavy, dense vegetation will absorb most flows, while barren or compacted areas will absorb limited runoff.

Peak rate mitigation

Level spreaders will not substantially decrease the overall discharge rate from a site.

Water quality improvement

While level spreaders are low in water quality pollutant removal, they are often an important BMP used in concert with other BMPs. For example, level spreaders can work effectively (and improve performance) with related BMPs such as filter strips and buffers. In addition, level spreaders can avoid erosion problems associated with concentrated discharges.

Construction Guidelines

The condition of the area downhill of a level spreader must be considered prior to installation. For instance, the slope, density and condition of vegetation, natural topography, and length (in the direction of flow) will all impact the effectiveness of a distributed flow measure. Areas immediately downhill from a level spreader may need to be stabilized, especially if they have been recently disturbed. Erosion control matting, compost blanketing, and/or riprap are the recommended measures for temporary and permanent downhill stabilization. Manufacturer's specifications should be followed for the chosen stabilization measure.

Maintenance

Compared with other BMPs, level spreaders require only minimal maintenance efforts, many of which may overlap with standard landscaping demands. The following recommendations represent the minimum routine inspection maintenance effort for level spreaders:

Once a month and after every heavy rainfall (greater than two inches):

1. Inspect the diverter box and clean and make repairs. Look for clogged inlet or outlet pipes and trash or debris in the box.

2. Inspect the forebay and level spreader. Clean and make repairs. Look for:

    - Sediment in forebay and along level spreader lip,
    - Trash and/or leaf buildup,
    - Scour, undercutting of level spreader,
    - Settlement of level spreader structure (no longer level; you see silt downhill below level spreader),
    - Fallen trees on level spreader, and
    - Stone from below the level spreader lip washing downhill.

3. Inspect the filter strip and the bypass swale and make repairs as needed. Look for:

    - Damaged turf reinforcement or riprap rolling downhill,
    - Erosion within the buffer or swale, and
    - Gullies or sediment flows from concentrated flows downhill of level spreader,

Once a year:

1. Remove any weeds or shrubs growing on level spreader or in swale.

Cost

Level spreaders are relatively inexpensive and easy to construct. There are various types of level spreaders, so costs will vary. Per foot material and equipment cost will range from $5 to $20 depending on the type of level spreader desired. Concrete level spreaders may cost significantly more than perforated pipes or berms, but they provide a more sure level surface, are easier to maintain, and more reliable.

Designer/Reviewer Checklist for Level Spreaders

ITEM	Page No.	YES	NO	N/A	NOTES
Avoidance of stormwater concentration as much as practical?	--				
Soil erodibility considered?	--				
Slope considered and appropriate? ➢ *Max Slope:* ***8%***	1,3				
Receiving vegetation considered?	4,5				
Located in undisturbed virgin soil?	3				
If not, will soil be properly compacted and stabilized?	--				
Acceptable minimum flow path length below level spreader?	--				
Level spreader length calculations performed? ➢ *Min length:* ***10 feet****; Max length:* ***200 feet***	3				
Erosion control matting, compost blankets, etc. provided?	4,5				
Appropriate vegetation selected for stabilization?	--				
Feasible construction process and sequence?	--				
Erosion and sedimentation control provided to protect spreader?	4,5				
Maintenance accounted for and plan provided?	5				
Soils stable or vegetation established before flows are directed to the level spreader?	3				
If used during construction, are accumulated soils removed?	3				

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

NATIVE REVEGETATION

Native revegetation includes the restoration of forest savanna (scattered trees among prairie plants), and/or prairie. Revegetation should primarily use native vegetation due to the numerous benefits, including reduced maintenance needs.

Figure 1 Native vegetation utilized in a wetland, Philadelphia, PA (USEPA, picasaweb)

Potential Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med/High
Commercial	Yes	Groundwater Recharge	Low/Med/High
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	High
Highway/Road	Limited	TP	High
Recreational	Yes	TN	Med/High
		Temperature	Med

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	Medium

Variations

- Prairie
- No-mow lawn area
- Woodland
- Constructed wetlands
- Buffer areas
- Replacement lawn areas

Key Design Features

- Minimize traditional turf lawn area
- Develop landscape plan using native materials, determining the most appropriate
- Protect areas during construction
- Use integrated pest management (IPM) approach

Site Factors

- Water table to bedrock depth: N/A
- Soils: Vegetation should match soil types
- Slope: Applicable on most slopes (up to 1H:1V)
- Potential hotspots: No
- Maximum drainage area: Optimal is five times (maximum 20 times) the revegetated area

Benefits

- Low long-term maintenance needs
- Improves water quality
- Reduces volume

Limitations

- Establishment period requires more intensive maintenance, such as weeding and watering

Description and Function

Using native plants to vegetate an area is an effective method of improving the quality and reducing the volume of site runoff. Native plants significantly change the soil medium by adding carbon, decreasing bulk density, and increasing infiltration rates by as much as a factor of 10 or more even in clay soils (see Bharati, et.al, 2002 and Fuentes, et.al, 2004).

Native species are generally described as those existing in a given geographic area prior to European settlement. Over time, native vegetation does not typically require significant chemical maintenance by fertilizers and pesticides. This results in additional water quality benefits. Native species are typically more tolerant and resistant to pest, drought, and other local conditions than non-native species. Landscape architects and ecologists specializing in native plant species are usually able to identify a wide variety of plants that meet these criteria anywhere in the state. Recommended Plan List for BMPs Appendix provides lists of commercially available native species. Additional information relating to native species and their use in landscaping is available from the Indiana Native Plant and Wildflower Society at www.inpaws.org.

In addition to chemical applications, minimum maintenance also means minimal mowing and irrigation in established areas. Native grasses and other herbaceous materials that do not require mowing or intensive maintenance are preferred. Because selecting such materials begins at the concept design stage, this BMP can generally result in a site with reduced runoff volume and rate, as well as significant nonpoint source load reduction/ prevention.

A complete elimination of traditional lawns as a site design element can be a difficult BMP to implement, given the extent to which the lawn as an essential landscape design feature is embedded in current national culture. Instead, the landscape design should strategically incorporate areas of native plantings – surrounding limited turf grass areas – to act as buffers that will capture and filter stormwater flowing off of turf grasses or pavements.

Native species, being strong growers with denser root and stem systems than turf grass (**Figure 2**), result in:

- A greater volume of water uptake (evapotranspiration)
- Improved soil conditions through organic material and macropore formation
- Carbon sequestration
- Enhanced infiltration

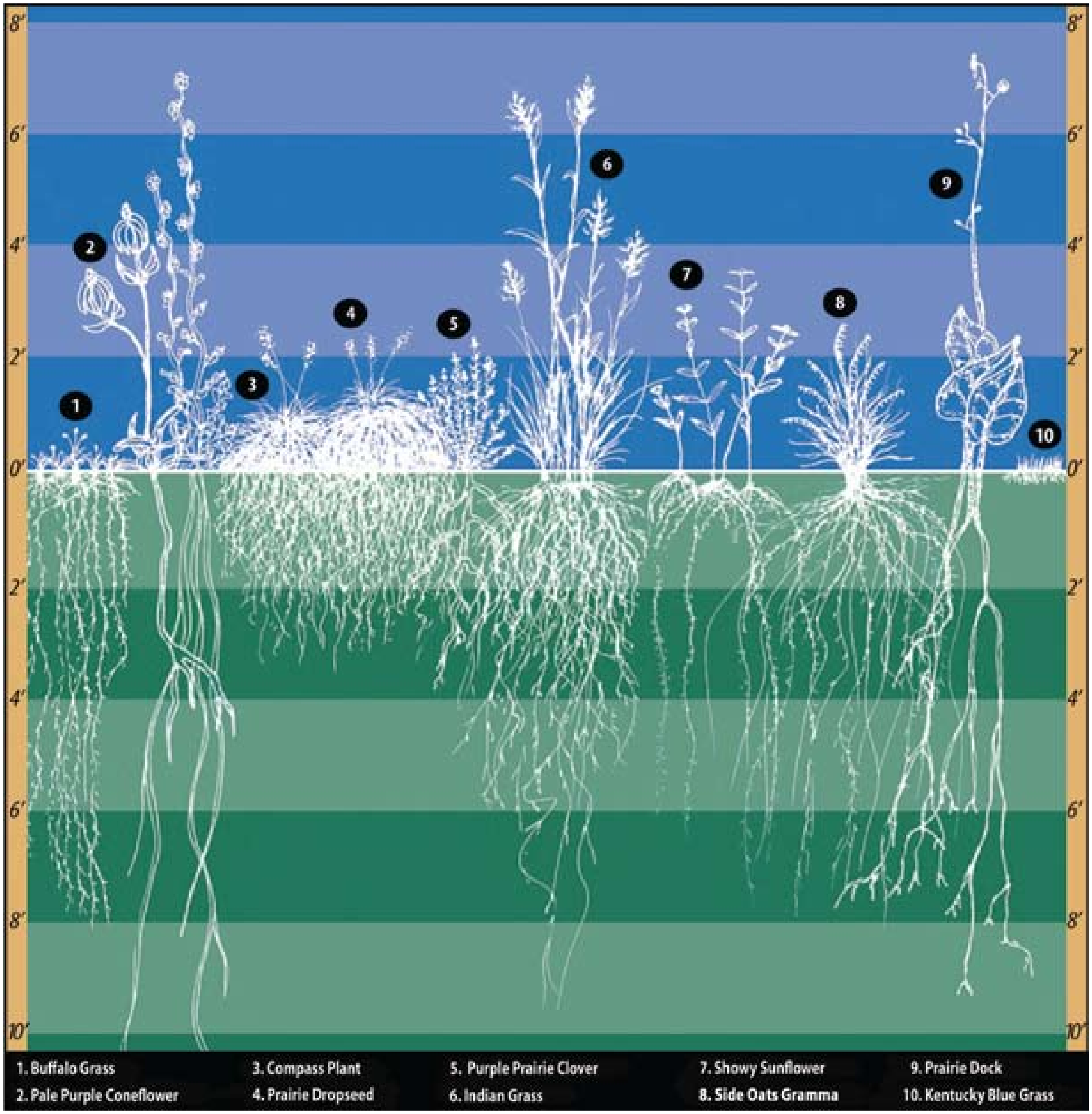

Figure 2 Native meadow species compared to turf grass
Source: JF New

If the objective is to revegetate an area with woodland species, the longer-term effect is a significant reduction in runoff volumes when contrasted with a conventional lawn planting. This decrease in runoff is caused by increases in interception, infiltration, evapotranspiration, and recharge. Peak runoff rate reduction also is achieved. Similarly, prairie reestablishment is also more beneficial than a conventional lawn planting. Again, these benefits are long term in nature and will not be apparent until the species have an opportunity to grow and mature (one advantage of the prairie planting is that this maturation process requires considerably less time than a woodland area).

In general, seeded prairie plantings grow roots in the first two years of planting, and by the third year, start to show substantial top growth. Therefore, a prairie planting may not be aesthetically pleasing during the first several years. Aesthetic expectations should therefore be adjusted accordingly. Posting signs explaining this fact to passersby can increase understanding and alleviate concerns about the look of the new planting. The signs can also explain the environmental benefits of planting native grasses.

Variations

Most newly-created native landscapes in Indiana fall under the category of either woodlands or prairies. Woodlands will provide shade, vertical structure, and a high level of rainfall interception in the long term. However, woodlands typically require a significant amount of time to mature. Prairies, on the other hand, have a tendency to establish and regain function rather quickly (3-10 years), and can provide lower-growing vegetation with highly attractive native grasses and wildflowers.

Species selection for any native landscape should be based on function, availability, and level of appropriateness for site conditions. Native species plantings can achieve variation in landscape across a variety of characteristics, such as texture, color, and habitat potential. Plant material should be selected based on tolerance to standing water as identified in Recommended Plant List for BMPs Appendix.

Properly selected mixes of flowering prairie species can provide seasonal color; native grasses offer seasonal variation in texture. Seed production is a food source for wildlife and reinforces habitat. In all cases, selection of native species should strive to achieve species variety and balance, avoiding creation of single-species or limited species “monocultures” which pose multiple problems. In sum, many different aspects of native species planting reinforce the value of native landscape restoration, typically increasing in their functional value as species grow and mature over time. Examples include:

- Prairie – Install forb/grass matrix that bears similarities to historic Indiana prairies and savannas

- No-mow lawn area – Install low-growing native grasses that are used as a substitute for lawn or cool-season grass plantings.

- Woodland – Install a balance of native trees, shrubs, forbs, grasses, and sedges that would historically be represented in Indiana woodlands.

- Constructed wetlands – Historic drained wetlands or existing artificial low areas may be planted with wetland species that will thrive in standing water or saturated conditions.

- Buffer areas – Bands of re-established native vegetation occurring between impermeable surfaces, lawns, or other non-native land uses and existing natural areas.

- Replacement lawn areas – Existing turf lawns may be converted to native prairies, wetlands, or woodlands to minimize maintenance while increasing stormwater benefits and wildlife habitat.

Applications

- Residential – Native landscapes can be incorporated into common areas of residential developments. Additionally, individual homeowners may incorporate native landscapes into their own properties. Native revegetation should also be used to provide buffers around any existing natural areas that are undisturbed within the residential development.

- Commercial – Common areas and open spaces within commercial developments may be planted with native species, as well as any created detention/retention basins or artificial waterways. Native revegetation should also be used to provide buffers around any existing natural areas that are undisturbed within the commercial development.

- Ultra Urban – Use of native revegetation in limited in ultra-urban settings because of the lack of available green space. Wherever possible, however, native species should be incorporated.

- Industrial – Use of native revegetation in industrial settings is very similar to that in commercial settings.

- Retrofit – Established turf grass may be converted into prairie, woodland, or wetland.

- Highway/Road – Native plants may be established in rights-of-way to minimize long-term maintenance while establishing linear habitat corridors.

Design Considerations

The basis for native revegetation design scheme begins with assessing the site for:

- Existing native vegetation,
- Soil,
- Hydrologic regimes,
- Sun exposure, and
- Aesthetics

Existing native vegetation is a good starting point for determining what can thrive on a given site. However, the designer must also consider and balance various factors in developing a successful plant list. The hydrologic patterns set the stage for where the moisture continuum plants will be most successful (easily found in native plant resource guides). The amount of sun and shade that a given species tolerates is also critical in successful plant selection (and is easy to find as well). Soil texture and pH (less often found in resources guides) will further narrow the plant choices. If soils are strongly acidic or basic, the pH will greatly influence and reduce plant choices. Once the potential plant list has run through the sieves of moisture, sun/shade, and soil characteristics, the designer will hopefully have a suite of loosely associated native plants that grow in similar conditions.

Besides the plants' physical requirements, there is the cultural issue of aesthetics to consider. Common issues that people have with native landscapes are the potential height and lack of cultivated appearance (tall and thin, smaller flowers, looser look, etc.). If the designed areas are highly visible, then these aesthetic issues can be addressed with good design principles and a solid understanding of native plants.

1. **Analyze site's physical conditions**

   The most important physical condition of the site is the topography, hydrology, and soil, each of which will guide protection activities and plant selection. Evaluate the soil using the USDA soil survey to determine important soil characteristics such as flooding potential, seasonal high water table, soil pH, soil moisture, and other characteristics. Evaluate the topography based on USGS maps or a topographical survey of the site.

2. **Analyze site's vegetative features**

   Existing vegetation present at the site should be examined to determine the overall strategy for vegetation restoration and establishment. Strategies will differ whether pre-existing conditions are pasture, overgrown abandoned field, mid-succession forest, or another type of setting. An effort to inventory existing vegetation for protection and to determine type of pre-settlement vegetation should be made to guide efforts.

   a. *Identify desirable species*: Use native tree and shrub species that thrive in local habitat. These species should be identified in the restoration site and protected. Several native vines and shrubs can provide an effective ground cover during establishment of the area, though they should be controlled to prevent herbaceous competition.

   b. *Identify undesirable species*: Control invasive plants prior to planting new vegetation.

   c. *Identify sensitive species*: Because many areas are rich in wildlife habitat and could potentially harbor wetland plant species, be aware of any rare, threatened, or endangered plant or animal species. Take care to protect sensitive species during restoration activities.

3. *Map the site*: Prepare an existing conditions sketch of the site that denotes important features, including stream width, length, stream bank condition, adjacent land uses, stream activities, desired width of buffer, discharge pipes, obstructions, etc.

4. *Create a design that meets multiple stakeholder objectives*

   a. *Landowner objectives*: Consider the current use of the existing vegetation, especially if the area will be protected by the landowner in perpetuity. Determine how the revegetated area will complement or conflict with existing and probable future uses of the property.

   b. *Local objectives:* Consider linking the revegetated area to an existing or planned green infrastructure system, which may include trails, parks, preserves, and wildlife habitat corridors. Evaluate how the new vegetation could help achieve local outdoor recreation goals.

   c. *Watershed objectives:* Examine the local watershed plan to identify goals related to establishing native plants. Have goals related to water quality been emphasized, or is wildlife habitat of primary concern? If no watershed plan has been prepared, examine other regional resource or recreation plans for reference to native plantings.

5. *Amend soil*: In those sites where soils have been disturbed, restore compromised soils by subsoiling and/or adding a soil amendment, such as compost. This will help in reestablishing its long-term capacity for infiltration and pollution removal.

6. Limit the development footprint as much as possible, preserving natural site features, such as vegetation and topography. In contrast to turf, "natural forest soils with similar overall slopes can store up to 50 times more precipitation than neatly graded turf." (Arendt, *Growing Greener*, pg. 81) If lawns are desired in certain areas of a site, they should be confined to those areas with slopes less than six percent.

7. Prairie restoration can reduce turf or create a buffer between turf and forest. Meadow buffers along forests help reduce off-trail trampling and direct pedestrian traffic in order to avoid "desire-lines" which can further concentrate stormwater.

   Prepare the site for a prairie planting by weeding well before planting and during the first year. Perennial weeds may require year-long smothering, repeated sprayings with herbicides, or repeated tillage with equipment that can uproot and kill perennial weeds.

   The site should be sunny, open, and well-ventilated, as prairie plants require at least a half a day of full sun.

   Erosion prone sites should be planted with a nurse crop (such as annual rye or seed oats) for quick vegetation establishment to prevent seed and soil loss. Steep slopes (25 percent or steeper) and areas subject to water flow should be stabilized with erosion blankets, selected to mitigate expected runoff volumes and velocities. Hydro-seeding is generally not recommended for native species. There is tremendous variation among seed suppliers; choose seeds with a minimum percent of non-seed plant parts. Native seed should also be PLS (Pure Live Seed) tested by a third party to gauge seed viability.

8. Converting turf grass areas to prairie requires that all turf be killed or removed before planting, and care taken to control weeds prior to planting.

9. Forest restoration includes planting of tree species, 12-18 inches in height, and shrubs at 18-24 inches, with quick establishment of an appropriate ground cover to stabilize the soil and prevent colonization of invasive species. Trees and shrubs should be planted on eight-

foot centers, with a total of approximately 430 trees per acre.

Reforestation can be combined with other volume control BMPs such as retentive berming, vegetated filter strips and swales. Plant selection should mimic the surrounding native vegetation and expand on the native species already found on the site. A mixture of native trees and shrubs is recommended and should be planted once a ground cover is established.

10. Ensure adequate stabilization, since native grasses, meadow flowers, and woodlands establish more slowly than turf. Stabilization can be achieved for forest restoration by establishing a ground cover before planting of trees and shrubs. When creating meadows, it may be necessary to plant a fast growing nurse crop with meadow seeds for quick stabilization. Annual rye can be planted in the fall or spring with meadow seeds and will establish quickly and usually will not present a competitive problem. Erosion prone sites should be planted with a nurse crop and covered with weed-free straw mulch, while steep slopes and areas subject to runoff should be stabilized with erosion control blankets suitable for the expected volume and velocity of runoff.

11. Prepare a landscape maintenance plan that identifies weeding plans, mowing goals, irrigation needs, and trimming of herbaceous perennials or key tree specimens, as needed.

Maintenance

Local land conservancies are excellent resources when considering the long-term stewardship of the area. If a site has critical value, a local conservancy may be interested in holding a conservation easement on the area, or may be able to provide stewardship services and assistance. Wild Ones (www.for-wild.org/) is a national organization with local chapters which may also provide stewardship resources.

Applying a carefully selected herbicide (Roundup® or similar glyphosate herbicide) around the protective tree shelters/tubes may be necessary, reinforced by selective cutting/manual removal, if necessary. This initial maintenance routine is often necessary for the first two to three years of growth and may be needed for up to five years until tree growth and tree canopy form, naturally inhibiting weed growth. Once shading is adequate, growth of invasive species and other weeds will be naturally prevented, and the woodland becomes self-maintaining. Survey the new woodland intermittently to determine if replacement trees should be provided. Keep in mind that some modest rate of planting failure is usual.

Prairie management is somewhat more straightfor-ward. A seasonal mowing or burning may be required, although care must be taken to make sure that any management is coordinated with essential reseeding and other important aspects of meadow reestablishment. In addition, burning needs to be coordinated with the local fire department and follow local regulations. In the first year, weeds must be carefully controlled and consistently mowed back to four to six inches tall when they reach 12-18 inches in height.

In the second year, continue to monitor and mow weeds and hand-treat perennial or rhizomatous weeds with herbicide. Weeds should not be sprayed with herbicide if the drift from the spray may kill large patches of desirable plants; weeds will most likely move in to these new open areas. If necessary, controlled spot herbicide applications may be used to treat invasive plants if the treatments can be completed without damage to off-target vegetation.

A prescribed burn should be conducted at the end of the second or beginning of the third growing season. If burning is not possible, the prairie should be mowed very closely to the ground instead. If possible or practical, the mowed material should be removed from the site to expose the soil to the sun. This helps encourage rapid soil warming which favors the establishment of "warm season" plants over "cool season" weeds. Long-term maintenance should incorporate burning or mowing on a two to five year cycle to minimize woody species growth while encouraging development of the native prairie species.

Stormwater Functions and Calculations

Volume and peak rate

Native revegetation will lower runoff volume and peak rates by lowering the runoff coefficient (i.e., curve number). Designers can receive runoff reduction recognition based on the square feet of trees or shrubs being added. Proposed trees and shrubs to be planted under the requirements of these BMPs can be assigned a curve number (CN) reflecting a woodlot in "good" condition associated with the pre-development underlying soil layer for an area of 200 square feet per tree or the estimated tree canopy, whichever is greater. For shrubs, the area should be 25 square feet per shrub. Calculation methodology to account for this BMP is provided under LID Approach in Post-Construction Water Quality Management Chapter of Technical Standards.

Water quality improvement

Landscape restoration using native species (which includes minimizing disturbance and maintenance), improves water quality preventively by minimizing the application of fertilizers and pesticides. Avoiding this nonpoint pollutant source is an important water quality objective.

Cost

Cost estimates for various aspects of native landscaping, including material and installation costs, are the following:

- $1,000-$2,500/acre for prairie installation or woodland understory installation
- $1,800-$2,600/acre for bare-root tree installation (10-foot spacing)
- $10-$20/plant for gallon-potted native perennial
- $2.50-$3.50/plant for plug-sized native perennial
- $250-$400/tree for balled-and-burlap tree installation

Costs for meadow re-establishment are lower than those for woodland, largely due to the need for tree installation. Again, such costs can be expected to be greater than installing a conventional lawn (seeding and mulching), although installation cost differences diminish when conventional lawn seeding is redefined in terms of conventional planting beds.

Cost differentials grow greater when longer term operating and maintenance costs are taken into consideration. If lawn mowing can be eliminated, or even reduced significantly to a once per year requirement, substantial maintenance cost savings result, often in excess of $2,000-$3,000 per acre per year.

If chemical application (fertilization, pesticides, etc.) can be eliminated, substantial additional savings result with use of native species. These reductions in annual maintenance costs resulting from a native landscape re-establishment quickly outweigh any increased installation costs that are required at project initiation. The aesthetic, water quality, and environmental protection benefits of native landscaping are clear. Nonetheless, implementation is often hindered because parties paying the higher up-front costs (usually the developer) are different than the parties reaping the benefits of reduced maintenance costs. Overcoming this impediment involves recognizing that native landscaping is another part of the "infrastructure" that communities must build into design in order to achieve the desired outcome of appearance and water quality protection.

Criteria to receive runoff reduction recognition for Native Revegetation

To receive runoff reduction recognition for native revegetation under a location regulation, the following criteria must be met:

- ☐ Area is protected by clearly showing the limits of disturbance on all construction drawings and delineated in the field.
- ☐ Area to receive runoff reduction recognition for trees is 200 square feet per tree or the estimated tree canopy, whichever is greater.
- ☐ Area to receive runoff reduction recognition for shrubs is 25 square feet per shrub.
- ☐ Area is located on the development project.
- ☐ Area has a maintenance plan that includes weeding and watering requirements from initial installation through ongoing maintenance.

Designer/Reviewer Checklist for Native Revegetation

ITEM	Page No.	YES	NO	N/A	NOTES
Avoidance of stormwater concentration as much as practical?	--				
Soil erodibility considered?	6				
Slope considered and appropriate?	6				
Existing and surrounding vegetation assessed, including desirable, sensitive, and non-native species?	5				
Site mapped?	5				
Does the design meet all stakeholder objectives, including storm-water, habitat, aesthetics, and timeframe for establishment?	5				
Does the soil require amendment?	6				
Erosion control matting, compost blankets, etc. provided as needed?	6				
Feasible construction process and sequence?	--				
Short and long-term maintenance accounted for and plan provided?	7				

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BMP Fact Sheet

PERVIOUS PAVEMENT WITH INFILTRATION

Pervious pavement is an infiltration technique that combines stormwater infiltration, storage, and structural pavement consisting of a permeable surface underlain by a storage reservoir. Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts, and other similar uses.

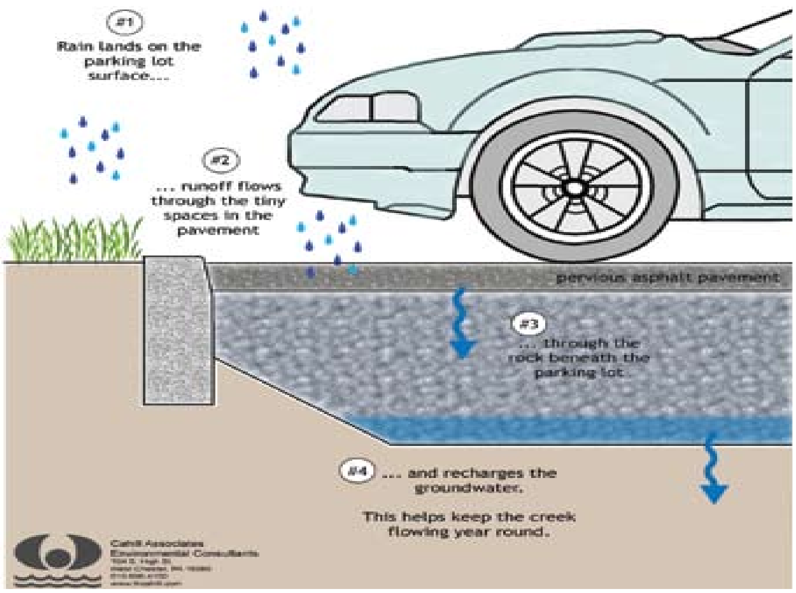

Figure 1 Pervious Pavement with infiltration schematic

Applications		Stormwater Quantity Functions	
Residential	Yes*	Volume	High
Commercial	Yes	Groundwater Recharge	High
Ultra Urban	Yes	Peak Rate	Med/High
Industrial	Yes*	Stormwater Quality Functions	
Retrofit	Yes*	TSS	High**
Highway/Road	Limited	TP	Med/High
Recreational	Yes	TN	Medium
		Temperature	High

Additional Considerations	
Cost	Medium
Maintenance	High
Winter Performance	Medium

*Applicable with special design considerations.

**Pretreatment for TSS is recommended.

Variations

- Porous asphalt
- Pervious concrete
- Permeable paver blocks
- Reinforced turf/gravel

Key Design Features

- Follow soil infiltration testing protocol (Appendix D4) and infiltration BMP guidelines
- Do not infiltrate on compacted soil
- Level storage bed bottoms
- Provide positive stormwater overflow from bed
- Surface permeability > 20"/hour

Site Factors

- Water table/Bedrock separation: two-foot minimum***
- Feasibility on steeper slopes: Low
- Potential hotspots: Not without design of pretreatment system

Benefits

- Volume control and groundwater recharge, moderate peak rate control
- Dual use for pavement structure and stormwater management

Limitations

- Pervious pavement not suitable for all uses
- High maintenance needs

*** Four feet recommended, if possible

Description and Function

A pervious pavement system consists of a porous surface course underlain by a storage reservoir placed on uncompacted subgrade to facilitate stormwater infiltration (**Figure 2)**. The storage reservoir may consist of a stone bed of uniformly graded, clean, and washed course aggregate with a void space of approximately 40 percent or other pre-manufactured structural storage units (see Infiltration BMP for detailed information on the use of structural storage units). The pervious pavement may consist of porous asphalt, pervious concrete, permeable paver blocks, or reinforced turf/gravel.

Stormwater drains through the surface course where it is temporarily held in the voids of the stone bed, and then slowly infiltrates into the underlying, uncompacted soil mantle (in some extreme cases, minimal compaction of the soil may be required). The stone bed can be designed with an overflow control structure so that during large storm events peak rates are controlled. At no time does the water level rise to the pavement level.

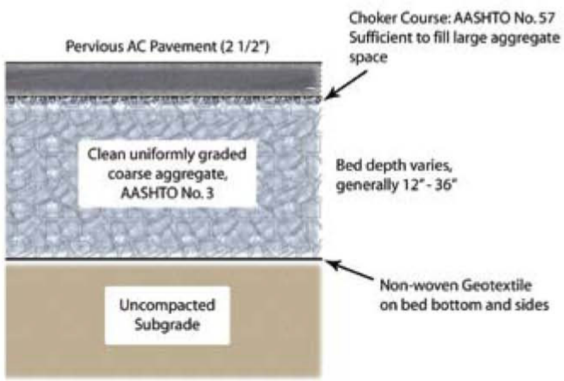

Figure 2 Example cross-section of porous asphalt system

A layer of nonwoven geotextile filter fabric separates the aggregate from the underlying soil, preventing the migration of fines into the bed. The bed bottoms should be level and uncompacted to allow for even and distributed stormwater infiltration.

If new fill is required, it should consist of additional stone and not compacted soil. It is recommended that a failsafe be built into the system in the event that the pervious surface is adversely affected and suffers reduced performance. Many designs incorporate a riverstone/rock edge treatment or inlets which are directly tied to the bed so that the stormwater system will continue to function despite the performance of the pervious pavement surface.

Pervious pavement is well suited for parking lots, walking paths, sidewalks, playgrounds, plazas, tennis courts, and other similar uses. Pervious pavement can be used in driveways if the homeowner is aware of the stormwater functions of the pavement. Pervious pavement roadways have seen wider application in Europe and Japan than in the U.S., although at least one U.S. system has been constructed successfully. (In Japan and the U.S., applying an open-graded asphalt pavement of one inch or less on roadways has been used to provide lateral surface drainage and prevent hydroplaning, but these are applied over impervious pavement on compacted subgrade. This application is not considered a stormwater BMP.)

Properly installed and maintained pervious pavement has a significant life span. For example, existing systems that are more than 20 years old continue to function successfully. Because water drains through the surface course and into the subsurface bed, freeze-thaw cycles do not tend to adversely affect pervious pavement.

Pervious pavement is most susceptible to failure difficulties during construction and, therefore, it is important that construction be undertaken in such a way as to prevent:

- Compacted underlying soil (except in certain limited conditions),
- Contaminated stone subbase with sediment and fines,
- Tracking of sediment or any temporary storage of soil on the pavement surface, and
- Drainage of sediment-laden waters onto pervious surface or into constructed bed.

Staging, construction practices, and erosion and sediment control must all be considered when using pervious pavements.

When properly designed, pervious pavement systems provide effective management of stormwater volume and peak rates. The storage reservoir below the pavement surface can be sized to manage both direct runoff and runoff generated by adjacent areas, such as rooftops. Because the stone bed provides storage, outlet structures can be designed to manage peak rates with the use of weir and orifice controls. A well-designed system can infiltrate the majority of frequent small storms on an annual basis while providing peak rate control for storms up to and including the 100-year frequency storm event.

Studies have shown that pervious systems have been very effective in reducing contaminants such as total suspended solids, metals, and oil and grease. Because pervious pavement systems often have zero net discharge of stormwater for small frequent storms, they provide effective water quality control. The pervious surface and underlying soils below the storage bed allow filtration of most pollutants.

However, care must be taken to prevent infiltration in areas where toxic/contaminated materials are present in the underlying soils or within the stormwater itself. When designed, constructed, and maintained according to the following guidelines, pervious pavement with underlying infiltration systems can dramatically reduce both the rate and volume of runoff, recharge the groundwater, and improve water quality.

In northern climates, pervious pavements have less of a tendency to form black ice and often require less plowing. Sand and other abrasives should never be used on pervious pavements, although salt may be used on pervious asphalt as long as it does not contain significant non-soluble particles. Commercial deicers may be used on pervious concrete. Pervious pavement surfaces often provide better traction for walking paths in rain or snow conditions.

Variations

Porous asphalt

Early work on porous asphalt pavement was conducted in the early 1970s by the Franklin Institute in Philadelphia. It consists of standard bituminous asphalt in which the fines have been screened and reduced, allowing water to pass through small voids. Pervious asphalt is typically placed directly on the stone subbase in a single 3½ to 4-inch lift that is lightly rolled to a finished thickness of 2½ to 3 inches.

Because porous asphalt is standard asphalt with reduced fines, it is similar in appearance to standard asphalt. Newer open-graded mixes for highway application give improved performance through the use of additives and higher-grade binders. Porous asphalt is suitable for use in any climate where standard asphalt is appropriate.

Pervious concrete

Pervious Portland Cement Concrete, or pervious concrete, was developed by the Florida Concrete Association. Like pervious asphalt, pervious concrete is produced by substantially reducing the number of fines in the mix in order to establish voids for drainage. In northern and mid-Atlantic climates such as Indiana, pervious concrete should always be underlain by a stone subbase designed for stormwater management and should never be placed directly onto a soil subbase.

While porous asphalt is very similar in appearance to standard asphalt, pervious concrete has a coarser appearance than conventional concrete. A clean, swept finish cannot be achieved. Care must be taken during placement to avoid working the surface and creating an impervious layer. Placement should be done by a contractor experienced with pervious concrete. Appropriately installed pervious concrete has proven to be an effective stormwater management BMP. Additional information pertaining to pervious concrete, including specifications, is available from the Indiana Ready Mixed Concrete Association (www.irmca.com).

Permeable paver blocks

Permeable paver blocks consist of interlocking units (often concrete) that provide some portion of surface area that may be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, parking areas, and low-speed streets. As new products are always being developed, the designer is encouraged to evaluate the benefits of various products with respect to the specific application.

Reinforced turf/gravel

Reinforced turf consists of interlocking structural units that contain voids or areas for turf grass growth or gravel and suitable for traffic loads and parking. Reinforced turf units may consist of concrete or plastic and are underlain by a stone and/or sand drainage system for stormwater management.

Reinforced turf/gravel applications are excellent for fire access lanes, overflow parking, and occasional-use parking (such as at religious and athletic facilities). Reinforced turf is also an excellent application to reduce the required standard pavement width of paths and driveways that must occasionally provide for emergency vehicle access.

Other

There are other proprietary products similar to pervious asphalt and concrete, but they use clear binders so that the beauty of the natural stone is visible. Material strength varies, so some of these products are not suitable for vehicular traffic Typical applications include tree pits, walkways, plazas, and playgrounds. There are also pervious pavements made using recycled tires.

Applications

Pervious pavements have been widely applied in retrofit situations when existing standard pavements are being replaced. Care must be taken when using pervious pavements in industrial and commercial applications where pavement areas are used for material storage or the potential for surface clogging is high due to pavement use. They have also been used extensively for parking areas, walkways, playgrounds, basketball courts, tennis courts, streets, and alleys.

Pervious pavement systems are often used to provide total site stormwater management where rooftops and other impervious surfaces are tied into the infiltration bed below the pavement surface. This can be an effective means to manage stormwater for a development site, while reducing land disturbance for stormwater BMPs.

If pervious pavement systems receive runoff from adjacent areas, proper sediment pretreatment for that runoff must be considered to prevent clogging of the storage bed. Typical pretreatment can be achieved by the use of properly maintained cleanouts, inlet sediment traps, and water quality inserts or filter devices.

It is recommended that direct surface sheet flow conveyance of large impervious areas to the pervious pavement surface be avoided. High sheet flow loading to pervious pavement surfaces can lead to premature clogging of the pavement surface. To avoid this, it is recommended that adjacent impervious areas be drained and conveyed to the infiltration bed via inlets and trench drains with proper sediment pretreatment.

Design Considerations

While evaluating the following design considerations, there are also several additional resources to consider when implementing pervious pavement. These include the Soil Infiltration Testing Protocol (Soil Infiltration Testing Protocol Appendix), the Recommendations for Materials are specific to porous asphalt and porous concrete (Recommended Materials Appendix), and additional steps set forth in the Introduction to Structural BMPs segment of this Appendix.

Siting

1. The overall site should be evaluated for potential pervious pavement/infiltration areas *early* in the design process because effective pervious pavement design requires consideration of grading.

2. A four foot clearance above the seasonally high water table and bedrock is recommended. A two foot clearance can be used but may reduce the performance of the infiltration BMP used.

3. Orientation of the parking bays along the existing contours will significantly reduce the need for cut and fill.

4. Pervious pavement and infiltration beds **should not be placed on areas of recent fill** or compacted fill. If fill is unavoidable, permeable stone subbase material should be used wherever possible (and applicable infiltration rates should be used in the design). Areas of historical fill (>5 years) may also be considered for pervious pavement.

5. In those areas where the threat of spills and groundwater contamination is likely, pretreatment systems, such as filters and wetlands, may be required before any infiltration occurs. In hot spot areas, such as truck stops and fueling stations, the appropriateness of pervious pavement must be carefully considered. A stone infiltration bed located beneath standard pavement, preceded by spill control and water quality treatment, may be more appropriate.

6. The use of pervious pavement must be carefully considered in areas where the pavement may be seal-coated or paved over due to lack of awareness, such as individual home driveways. In those situations, a system that is not easily altered by the property owner may be more appropriate. An example would include an infiltration system constructed under a conventional driveway. Educational signage at pervious pavement installations can encourage proper maintenance and is recommended.

7. In areas with poorly draining soils, infiltration beds below pervious pavement may be designed to slowly discharge to adjacent swales, wetlands, or bioretention areas. Only in extreme cases (e.g., industrial sites with contaminated soils) will the aggregate bed need to be lined to prevent infiltration.

Design

1. Bed bottoms must be level (0 percent slope) or nearly level. Sloping bed bottoms will lead to areas of ponding and reduced stormwater distribution within the bed. However, beds may be placed on a slope by benching or terracing parking bays (**Figure 3**). Orienting parking bays along existing contours will reduce site disturbance and cut/fill requirements.

Figure 3 Slope stepping with berms Source: Andropogon

2. All systems should be designed with an overflow system. Water within the subsurface stone bed should typically never rise to the level of the pavement surface. Inlet boxes can be used for cost-effective overflow structures. All beds should empty within 72 hours, preferably within 48 hours.

3. While infiltration beds are typically sized to handle the increased volume from a two-year design storm, they must also be able to convey and mitigate the peak of the less-frequent, more-intense storms, such as the 100-year storm. Control in the beds is usually provided in the form of an outlet control structure. A modified inlet box with an internal weir and low-flow orifice is a common type of control structure (**Figure 4**). The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it always must include positive overflow from the system to prevent surface ponding.

4. A weir plate or weir within an inlet or overflow control structure may be used to maximize the water level in the stone bed while providing sufficient cover for overflow pipes (Figure 3).

5. The subsurface bed and overflow may be designed and evaluated in the same manner as a detention basin to demonstrate the

mitigation of peak flow rates. In this manner, the need for a detention basin may be eliminated or significantly reduced in size.

8. Perforated pipes can also be used as underdrains where necessary. Underdrains must be double-walled. Underdrains can ultimately discharge to daylight or to another stormwater system. They should be accessible for inspection and maintenance via cleanouts, overflow devices (Figure 4), or other structures.

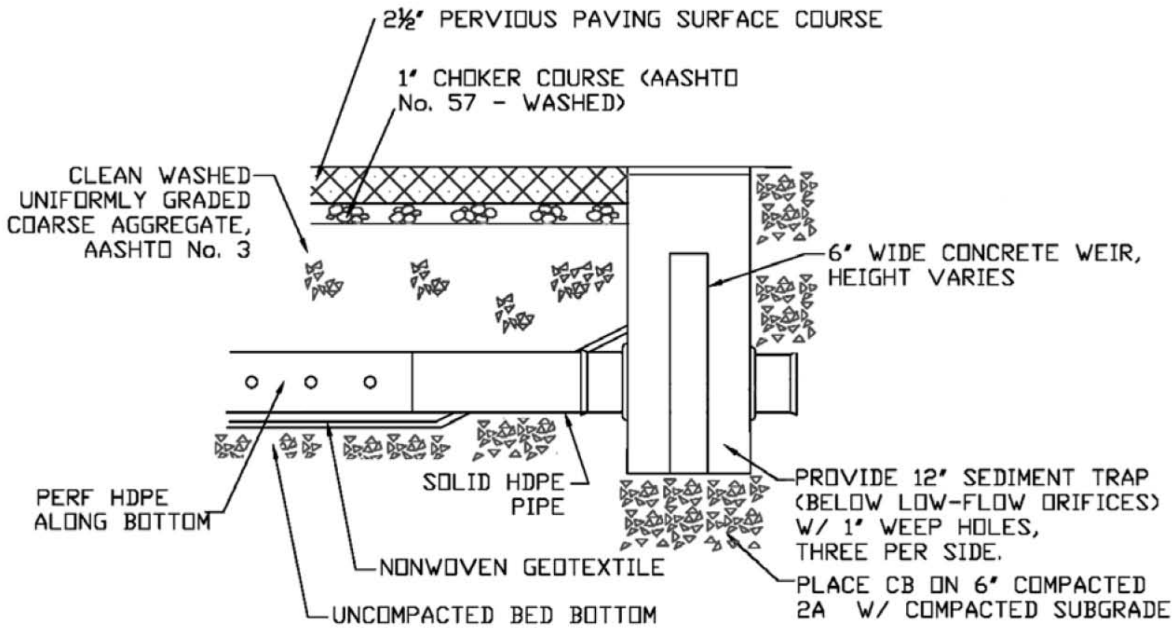

Figure 4 Example cross-section of porous asphalt system

6. Pervious pavement installations should have a backup method for water to enter the stone storage bed in the event that the pavement fails or is altered. In uncurbed lots, this backup drainage may consist of an unpaved one-to-two foot wide stone edge drain connected directly to the bed. In curbed lots, inlets with sediment traps may be used at low spots. Backup drainage elements will ensure the functionality of the infiltration system if the pervious pavement is compromised.

7. Perforated pipes along the bottom of the bed may be used to evenly distribute runoff over the entire bed bottom (especially if runoff from adjacent areas is being brought into the bed). Continuously perforated pipes should connect structures (such as cleanouts and inlet boxes). Pipes may lay flat along the bed bottom and connect to the overflow structure (**Figure 4**). Depending on size, these pipes may provide additional storage volume.

9. Sediment transport to pervious systems should be minimized as much as possible to reduce maintenance requirements and extend the life of these systems. If roof leaders and area inlets convey water from adjacent areas to the bed, then native vegetation, water quality inserts, and/ or sumped inlets should be used to prevent the conveyance of sediment and debris into the bed. Areas of impervious pavement draining directly onto pervious pavements should also be minimized as they can lead to clogging near the impervious-pervious boundary.

10. Infiltration areas should be located within the immediate project area in order to control runoff at its source. Expected use and traffic demands should also be considered in pervious pavement placement. An impervious

water stop should be placed along infiltration bed edges where pervious pavement meets standard impervious pavements.

11. The underlying infiltration bed is typically 8 to 36 inches deep and comprised of clean, uniformly graded aggregate with approximately 40 percent void space. Local aggregate availability typically dictates the size of the aggregate used. The critical requirements are that the aggregate be uniformly graded, clean washed, and contain a significant void content. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, site grading, and structural needs.

12. Proper pervious pavement applications are resistant to freeze-thaw problems because of their permeable and open-graded components (the pavement surface should not be saturated and the base has a high void content which allows for expansion). In somewhat frost-susceptible soils, it may be necessary to increase the minimum bed depth to 14-22 inches (depending on loading and specific soil conditions). In extremely susceptible soils, the bed and/or improved soils can be placed down to the full frost depth (Smith, 2006).

13. While most pervious pavement installations are underlain by an aggregate bed, alternative subsurface storage products may also be used. These include a variety of proprietary plastic units that contain much greater storage capacity than aggregate, at an increased cost.

Stormwater Functions and Calculations

Infiltration area

The infiltration area is defined as the plan area of the storage reservoir under the pervious pavement. The minimum infiltration area should be based on the following equation:

Minimum infiltration area = Contributing impervious area (including pervious pavement) / $5^{\#}$

$^{\#}$ - May be increased depending on soil infiltration capacity (where soils are Type A or rapidly draining).

Volume reduction

Pervious pavements with infiltration provide an excellent means of capturing and infiltrating runoff. The storage bed below the pavement provides runoff volume storage during storm events, while the undisturbed subgrade allows infiltration of runoff into the underlying soil mantle. The total volume reduction can be estimated by summing the storage and infiltration volumes described below.

Storage volume = Depth$^{\#}$ (ft) * Area (ft^2) * Void space (i.e., 0.40 for aggregate)

$^{\#}$ - Depth is the depth of the water stored during a storm event, depending on the drainage area, conveyance to the bed, and outlet control.

Infiltration volume = Bed bottom area (ft^2) * Infiltration design rate (in/hr) * Infiltration period$^{\#}$ (hr) * (1/12)

$^{\#}$ - Infiltration period is the time when bed is receiving runoff and capable of infiltrating at the design rate. Not to exceed 72 hours.

Peak rate mitigation

Properly designed pervious pavement systems provide effective management of peak rates. The infiltration bed below the pavement acts as a storage reservoir during large storm events, even while runoff exfiltrates through the soil mantle through the process of infiltration. Outlet structures can be designed to manage peak rates with the use of weir and orifice controls and carefully designed systems may be able to manage peak rates for storms up to and including the 100-year storm.

Water quality improvement

Pervious pavement systems are effective in reducing pollutants such as total suspended solids, metals, and oil and grease. Both the pervious pavement surface and the underlying soils below the infiltration bed allow pollutant filtration.

When pervious pavement systems are designed to capture and infiltrate runoff volumes from small storm events, they provide very high pollutant reductions because there is little if any discharge of runoff carrying the highest pollutant loads. Pervious pavement systems require pretreatment of TSS when adjacent areas drain to them, resulting in a high reduction of TSS and other particulates. However, pervious pavement systems will provide limited treatment of dissolved pollutants, such as nitrates. Typical ranges of pollutant reduction efficiencies for pervious pavements are listed as follows:

- TSS[#] – 65-100%
- TP – 30-90%
- NO_3 – 30%

[#] - Pretreatment for TSS is recommended if adjacent areas drain to pervious pavement

Construction Guidelines

1. Follow the Recommendations for Materials that are specific to porous asphalt and porous concrete in Recommended Materials Appendix.

2. Due to the nature of construction sites, pervious pavement and other infiltration measures should be installed toward the end of the construction period, if possible. Infiltration beds under pervious pavement may be used as temporary sediment basins or traps provided that they are not excavated to within 12 inches of the designated bed bottom elevation. Once the site is stabilized and sediment storage is no longer required, the bed is excavated to its final grade and the pervious pavement system is installed.

3. The existing subgrade under the bed areas should **not** be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement. (Minor areas of unavoidable compaction can be partially remediated by scarifying the soil; see below.)

   Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material should be removed with light equipment and the underlying soils scarified to a minimum depth of six inches with a York rake (or equivalent) and light tractor. All fine grading should be done by hand. All bed bottoms are level grade.

4. Earthen berms (if used) between infiltration beds may be left in place during excavation. These berms do not require compaction if proven stable during construction.

5. Geotextile and bed aggregate should be placed immediately after approval of subgrade preparation. Geotextile is to be placed in accordance with manufacturer's standards and recommendations.

   Adjacent strips of geotextile should overlap a minimum of 18 inches. It should also be secured at least four feet outside of bed in order to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. As the site is fully stabilized, excess geotextile along bed edges can be cut back to bed edge.

6. Clean (washed) uniformly graded aggregate is placed in the bed in eight-inch lifts. Each layer should be lightly compacted, with construction equipment kept off the bed bottom. Once bed aggregate is installed to the desired grade, approximately one inch of choker base course crushed aggregate should be installed uniformly over the surface in order to provide an even surface for paving (if required).

7. Cement mix time: Mixtures should be produced in central mixers or in truck mixers. When concrete is delivered in agitating or non-agitating units, the concrete should be mixed in the central mixer for a minimum of 1.5 minutes or until a homogenous mix is achieved. Concrete mixed in truck mixers should be mixed at the speed designated as mixing speed by the manufacturer for 75-100 revolutions.

8. The Portland Cement aggregate mixture may be transported or mixed onsite and should be

used within one hour of the introduction of mix water, unless otherwise approved by an engineer. This time can be increased to 90 minutes when using the specified hydration stabilizer. Each truck should not haul more than two loads before being cycled to another type concrete. Prior to placing concrete, the subbase should be moistened and in a wet condition. Failure to provide a moist subbase will result in reduced strength of the pavement.

9. A minimum of 30 revolutions at the manufacturer's designated mixing speed is required following any water added to the mix. Discharge should be a continuous operation and completed as quickly as possible. Concrete should be deposited as close to its final position as practicable and such that fresh concrete enters the mass of previously placed concrete.

10. Placing and finishing concrete equipment: The contractor should provide mechanical equipment of either slipform or form riding with a following compactive unit that will provide a minimum of 10 psi vertical force. The pervious concrete pavement will be placed to the required cross section and should not deviate more than +/- 3/8 inch in 10 feet from profile grade.

    Placement should be continuous and spreading and strikeoff should be rapid. It is recommended to strike off about ½ to ¾ inch above the forms to allow for compaction. This can be accomplished by attaching a temporary wood strip above the top of the form to bring it to the desired height. After strikeoff, the strips are removed and the concrete is consolidated to the height of the forms.

11. Consolidation should be accomplished by rolling over the concrete with a steel roller, and compacting the concrete to the height of the forms. Consolidation should be completed within 10 minutes of placement to prevent problems associated with rapid hardening and evaporation. After mechanical or other approved strike-off and compaction operation, no other finishing operation is needed. The contractor will be restricted to pavement placement widths of a maximum of 15 feet.

12. Jointing: Control (contraction) joints should be installed at maximum 20-foot intervals. They should be installed at a depth of ¼ the thickness of the pavement. These joints can be installed in the plastic concrete or saw cut. However, installing in the plastic concrete is recommended. Joints installed in the plastic concrete should be constructed using a small roller (salt or joint roller) to which a beveled fin with a minimum depth of ¼ the thickness of the slab has been welded around the circumference of a steel roller. When this option is used it should be performed immediately after roller compaction and prior to curing. If saw cut, the procedure should begin as soon as the pavement has hardened sufficiently to prevent raveling and uncontrolled cracking (normally just after curing).

    Transverse construction joints should be installed whenever placing is suspended a sufficient length of time that concrete may begin to harden. In order to assure aggregate bond at construction joints, a bonding agent suitable for bonding fresh concrete should be brushed, tolled, or sprayed on the existing pavement surface edge. Isolation (expansion) joints will not be used except when pavement is abutting slabs or other adjoining structures.

13. Curing procedures should begin within 15 minutes after placement. The pavement surface should be covered with a minimum six millimeter thick polyethylene sheet or other approved covering material. Prior to covering, a fog or light mist should be sprayed on the surface. The cover should overlap all exposed edges and should be completely secured (without using dirt) to prevent dislocation due to winds or adjacent traffic conditions.

14. Porous asphalt should not be installed on wet surfaces or when the ambient air temperature is below 50 degrees Fahrenheit. The

temperature of the bituminous mix should be determined by the results of the Draindown test (ASTM D6390), but typically ranges between 275 degrees Fahrenheit and 325 degrees Fahrenheit (as determined by the testing and recommendations of the asphalt supplier).

Pervious pavement should be laid in one lift directly over the storage bed and stone base course to a 2.5- to 3-inch finished thickness. Compaction of the surface course should take place when the surface is cool enough to resist a 10-ton roller. One or two passes is all that is required for proper compaction. More rolling could cause a reduction in the surface course porosity.

15. Do not place Portland Cement pervious pavement mixtures when the ambient temperature is 40 degrees Fahrenheit or lower, unless otherwise permitted in writing by the engineer.

16. Mixing, placement, jointing, finishing, and curing do not apply to permeable paver systems. A manual on Permeable Interlocking Concrete Pavements from the Interlocking Concrete Pavement Institute (Smith, 2006) offers detailed guidance on the design and construction of permeable paver systems.

17. After final pervious asphalt or concrete installation, no vehicular traffic of any kind should be permitted on the pavement surface until cooling and hardening or curing has taken place, and not within the first 72 hours (many permeable paver systems can be used right away). The full permeability of the pavement surface should be tested by applying clean water at the rate of at least five gallons per minute over the surface using a hose or other distribution device. All water should infiltrate directly without puddle formation or surface runoff.

Maintenance

The primary goal of pervious pavement maintenance is to prevent the pavement surface and/or underlying infiltration bed from being clogged with fine sediments. To keep the system clean and prolong its life span, the pavement surface should be vacuumed twice per year with a commercial cleaning unit. Pavement washing systems or compressed air units are generally not recommended but may be acceptable for certain types of pavement. All inlet structures within or draining to the infiltration beds should also be cleaned out twice a year.

Planted areas adjacent to pervious pavement should be well maintained to prevent soil washout onto the pavement. If any washout does occur, immediately clean it off the pavement to prevent further clogging of the pores. Furthermore, if any bare spots or eroded areas are observed within the planted areas, they should be replanted and/or stabilized at once. Planted areas should be inspected twice a year. All trash and other litter should be removed during these inspections.

Superficial dirt does not necessarily clog the pavement voids. However, dirt that is ground in repeatedly by tires can lead to clogging. Therefore, trucks or other heavy vehicles should be prevented from tracking or spilling dirt onto the pavement. Furthermore, all construction or hazardous materials carriers should be prohibited from entering a pervious pavement lot.

Potholes in pervious pavement are unlikely, though settling might occur if a soft spot in the subgrade is not removed during construction. For damaged areas of less than 50 square feet, a depression could be patched by any means suitable with standard pavement, with the loss of porosity of that area being insignificant. The depression can also be filled with pervious mix.

If an area greater than 50 sq. ft. is in need of repair, approval of patch type must be sought from either the engineer or owner. If feasible, permeable pavers can be taken up and then simply re-installed (replacing damaged pavers if necessary). **Under no circumstance should the pavement surface ever be seal-coated**. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

Pervious pavement maintenance considerations are summarized below:

Prevent clogging of pavement surface with sediment

- Vacuum pavement twice a year,
- Maintain planted areas adjacent to pavement,
- Immediately clean any soil deposited on pavement,
- Do not allow construction staging, soil/mulch storage, etc., on unprotected pavement surface, and
- Clean inlets draining to the subsurface bed twice a year.

Snow/Ice removal

- Pervious pavement systems generally perform better and require less treatment than standard pavements,
- Do not apply abrasives such as sand or cinders on or adjacent to pervious pavement,
- Snow plowing is fine but should be done carefully (i.e., set the blade slightly higher than usual), and
- Salt application is acceptable, although alternative deicers are preferable.

Repairs

- Surface should never be seal-coated,
- Damaged areas less than 50 sq. ft. can be patched with pervious or standard pavement,
- Larger areas should be patched with an approved pervious pavement,
- Permeable pavers should be repaired/replaced with similar permeable paver block material, and
- Permeable pavers and gravel pavers may require the addition of aggregate on an annual basis or as needed, in order to replenish material used to fill in the open areas of the pavers. Turf pavers may require reseeding if bare areas appear.

Winter Considerations

Pervious pavement systems should perform equally well in the winter, provided that infiltration bed design considers the soil frost line, and proper snow removal and deicing procedures are followed. Winter maintenance for pervious pavement may be necessary but is sometimes less intensive than that required for a standard pavement (especially for pervious asphalt). The underlying stone bed tends to absorb and retain heat so that freezing rain and snow melt faster on pervious pavement. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms.

Abrasives such as sand or cinders should not be applied on or adjacent to the pervious pavement. Snow plowing is fine, provided it is done carefully (i.e., by setting the blade slightly higher than usual, about an inch). Salt with low non-soluble solids content is acceptable for use as a deicer on the pervious pavement. Non-toxic, organic deicers applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferred.

Cost

The majority of added cost of a pervious pavement/infiltration system lies in the underlying stone bed, which is generally deeper than a conventional subbase and wrapped in geotextile. Costs may also be higher in areas where experienced contractors are not readily available. However, these additional costs are often offset by the significant reduction in the required number of inlets and pipes. Also, since pervious pavement areas are often incorporated into the natural topography of a site, there is generally less earthwork and/or deep excavations involved. Furthermore, pervious pavement areas with subsurface infiltration beds often eliminate the need (and associated costs, space, etc.) for detention basins. When all of these factors are considered, pervious pavement with infiltration has often proven itself less expensive than impervious pavement with associated stormwater management.

- Porous asphalt, with additives, is generally 15 percent to 25 percent higher in cost than standard asphalt on a unit area basis. Unit costs for pervious asphalt (without infiltration bed) range from about $\$4/ft^2$ to $\$5/ft^2$.

- Pervious concrete as a material is generally more expensive than asphalt and requires more labor and expertise to install. Unit cost of a six-inch-thick pervious concrete (without infiltration bed) section is about $\$4/ ft^2$ to $\$6/ ft^2$.

- Permeable paver blocks vary in cost depending on type and manufacturer.

- NOTE: The data provided are based on average market costs. For greater accuracy, a site and market-specific cost estimate should be developed.

Designer/Reviewer Checklist for Pervious Pavement with Infiltration Bed

Type of pervious pavement(s) proposed: ____

Source of mix design or material source: ____

ITEM	Page No.	YES	NO	N/A	NOTES
Appropriate application of pervious pavement (e.g., use, traffic loading, slopes)?	--				
Was the Soil Infiltration Testing Protocol followed?	1				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured?	1				
Was the Infiltration BMP followed?	1				
Two-foot minimum separation between the bed bottom and bedrock/SHWT?	1				
Soil permeability acceptable?	--				
If not, appropriate underdrain provided?	--				
Adequate separations from wells, structures, etc.?	--				
Natural, uncompacted soils?	2				
Level infiltration area (bed bottom)?	1,5				
Excavation in pervious pavement areas minimized?	-				
Hotspots/pretreatment considered?	1,5				
Loading ratio below 5:1?	--				
Storage depth limited to two feet?	--				
Drawdown time less than 48 hours?	5				
Positive overflow from system?	1,5				
Erosion and Sedimentation control?	2				
Feasible construction process and sequence?	--				
Geotextile specified?	2				
Clean, washed, open-graded aggregate specified?	2				
Properly designed/specified pervious pavement surface?	8-10				
Maintenance accounted for and plan provided?	10				
Signage provided?	5				

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BMP Fact Sheet

PLANTER BOXES

Planter boxes receive runoff from multiple impervious surfaces, which is used for irrigation of the vegetation in the planter box preventing stormwater from directly draining into nearby sewers. They also play an important role in urban areas by minimizing stormwater runoff, reducing water pollution, and creating a greener and healthier appearance of the built environment by providing space for plants and trees near buildings and along streets. There are three main types of planter boxes which can be used on sidewalks, plazas, rooftops, and other impervious areas: contained, infiltration, and flow-through.

Figure 1 Streetside planter, Portland, OR (city of Portland, Bureau of Environmental Services)

Potential Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Yes	Peak Rate	Low
Industrial	Limited	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Medium
Highway/Road	No	TP	Medium
Recreational	Yes	TN	Low/Med
		Temperature	Low/Med

Additional Considerations	
Cost	High
Maintenance	Medium
Winter Performance	Medium

Variations

- Contained
- Infiltration
- Flow-through

Key Design Features

- May be designed as pretreatment
- May be designed to infiltrate
- Captures runoff to drain out in three to four hours after a storm event
- Receives less than 15,000 ft^2 of impervious area runoff
- Planters should be made of stone, concrete, brick, or pressure-treated wood

Benefits

- Enhances the area where they are placed
- Potential air quality and climate benefits
- Can be used in a wide range of areas, including ultra-urban

Limitations

- Limited stormwater quantity/ quality benefits
- Relatively high cost due to structural components

Description and Function

Planter boxes receive runoff from multiple impervious surfaces, including rooftops, sidewalks, and parking lots. Runoff is used for irrigation purposes, and the vegetation in the planter box absorbs stormwater and releases it back into the atmosphere through evapotranspiration. Boxes can take any form and can be made out of a variety of materials, although many are constructed from wood.

Construction specifications are critical to ensure that an appropriate volume of runoff from smaller storms "feeds" the carefully selected vegetation types in the boxes; however, consistent watering is necessary during dry periods.

In general, planter boxes must be carefully designed to accommodate the desired amount of runoff. In addition, plantings must be carefully selected, and boxes must be carefully maintained, to accomplish stormwater objectives, and perhaps, most importantly, to succeed in a landowner's overall landscaping objectives.

Stormwater benefits of planter boxes include reduction in runoff volumes and some reduction in peak rates of runoff. Boxes which overflow also effectively reduce peak rates of runoff. Depending on the type of box selected, evapotranspiration will increase along with infiltration and groundwater recharge. Water quality may benefit, depending upon how much runoff is directed into the ground and prevented from worsening erosive stream flows.

When well designed, installed, and maintained, planter boxes are extremely attractive additions to homes, commercial businesses, and office buildings. In fact, an essential objective in developing planter boxes is to enhance overall landscape aesthetics. Boxes are ideal for buffers around structures, foundation plantings, providing seat walls, and for defining walkways, patios, terraces, drives, and courtyards.

Variations

Of all the BMPs listed in this manual, planter boxes are probably the most adaptable to all types of sites with all types of site constraints. The infiltration variation is influenced by all factors which are limiting to any infiltration-oriented BMP (i.e., bedrock/seasonal high water table at or close to the surface, very poorly draining soils, etc., all of which are described in the Infiltration BMP of this manual). However, both the contained and flow-through variations can be used on virtually every type of site - large or small, front yard or backyard, flat or sloping, shady or sunny.

Contained

Contained planter boxes (**Figure 2**) are generally traditional planters that have weep holes to drain excess water from the planter. They effectively reduce impervious area by retaining rainwater which slows stormwater runoff from draining into sewers. Contained planters are used for planting trees, shrubs, perennials, and annuals. The planter is either prefabricated or permanently constructed in a variety of shapes and sizes. Planters are typically placed on impervious surfaces like sidewalks, plazas, and rooftops. Contained planters may drain onto impervious surfaces through their base or into an overflow structure.

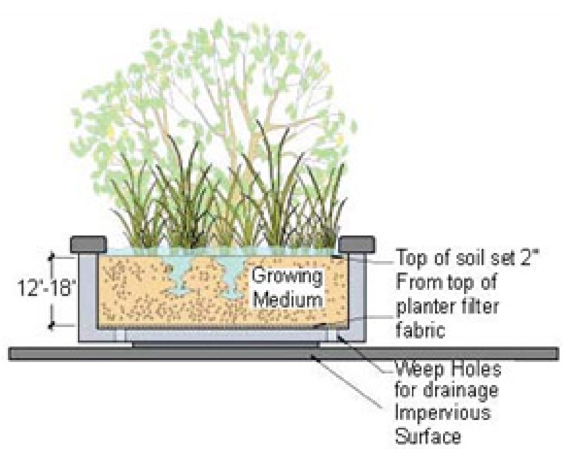

Figure 2 Schematic of Contained Planter Box
Source: City of Portland, OR, Bureau of Environmental Services

Native vegetation should be used in contained planter boxes (Recommended Plant List for BMPs

Appendix). They are hardy and self-sustaining with little need for fertilizers or pesticides. Irrigation needs to be monitored, since plants will need to be watered during dry periods. Sensors can help to regulate moisture in the planter box, ensuring consistent moisture. Smaller trees are highly encouraged because of the canopy and shade they will provide, reducing the urban heat island effect. Planters should be constructed of stone, concrete, brick, wood, or any other suitable material.

This type of planter box can be installed to retrofit an existing urban streetscape or large area of pavement, such as at an entryway to a building.

Infiltration

An infiltration planter box (**Figure 3**) is designed to allow runoff to filter through the planter soils (thus capturing pollutants) and then infiltrate into native soils below the planter. These planters are generally constructed to be flush with surrounding paved areas. The planter is sized to accept runoff and temporarily store the water in a reservoir on top of the soil. Different design variations are encouraged, but should allow a minimum delay in stormwater runoff capture of three to four hours after a wet weather event.

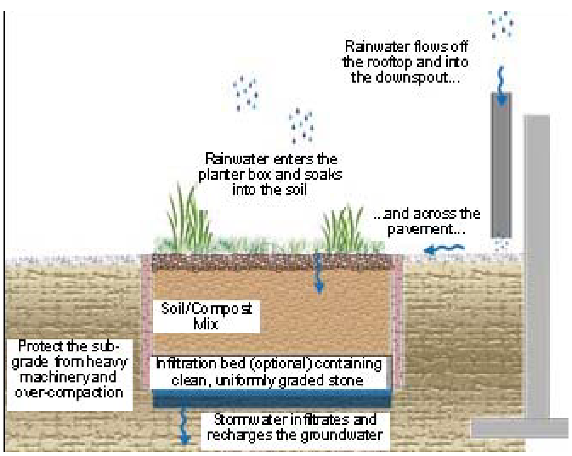

Figure 3 Schematic of Infiltration Planter Box

Recommended vegetation includes native rushes, reeds, sedges, irises, dogwoods, and currants. Also, the dimensions of the sand/gravel area used in these designs should be determined by an engineer and designed to receive less than approximately 15,000 square feet of impervious area runoff. The minimum planter width is typically 30 inches with no minimum length or required shape.

Suggested structural elements of infiltration planter boxes are stone, concrete, brick, or pressure-treated wood. In general, infiltration facilities should be greater than 10 feet from structures and at least five feet from an adjoining property line or as required by local ordinances.

Flow-through

The flow-through planter box (**Figure 4**) is completely contained and drains to a stormwater system. These planters are designed with an impervious bottom or are placed on an impervious surface. Pollutant reduction is achieved as the water filters through the soil/ growing medium. Flow control is obtained by ponding runoff above the soil and in a gravel layer beneath it. In most storm events, runoff flows through the soil into the gravel layer and is slowly discharged via the perforated pipe. In more extreme events, inflow may exceed the capacity of the soil and some runoff may be discharged through surface overflow. This type of planter can be used adjacent to a building if the planter box and/or building are adequately waterproofed to allow for saturated soil and temporary ponded runoff next to the building.

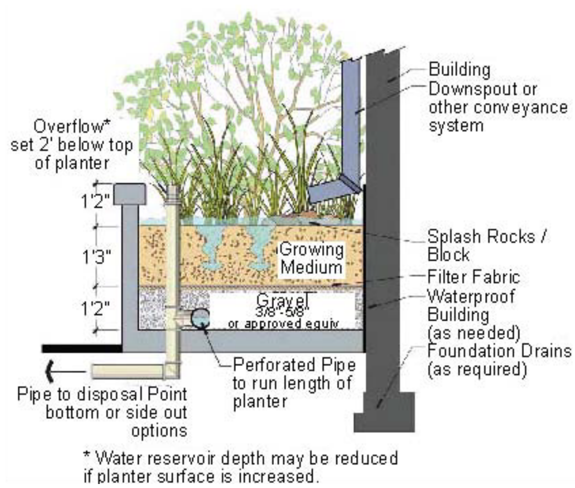

Figure 4 Schematic of Flow-through Planter Box

Flow-through planter boxes should be designed to retain water for no more than three to four hours after an average storm event. Recommended vegetation includes native rushes, reeds, sedges, irises, dogwoods, and currants. The minimum planter width is typically 18 inches with no minimum length or required shape. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff.

Potential Applications

Planter boxes can be used in urbanized areas of high pollutant loads. They are especially applicable where there is limited area for construction of other BMPs. Planter boxes may be used as a pretreatment BMP for other BMPs such as wet ponds or infiltration systems. Areas that would benefit from using a planter box include:

- Parking garage
- Office building
- Residential building
- Other building use (commercial, light industrial, institutional, etc.)
- Transportation facilities
- Urban streetscapes

Design Considerations

- **Suggested structural elements** of planters are stone, concrete, brick, or pressure-treated wood. Flow-through planters are completely contained and, therefore, not designed to drain directly into the ground. Pipes can also be designed to transport water to an approved disposal point. It is recommended that planter boxes have setback distances of 10 feet from structures and five feet from property lines, unless the planter height is less than 30 inches or as required by local ordinances.

- The **flow entrance/inflow** must be designed to prevent erosion in the planter box. Some alternatives include gravel, splash blocks, perforated pipe, and erosion control mats.

- A **positive overflow system** should be designed to safely convey away excess runoff. The overflow can be routed to the surface in a non-erosive manner or to another stormwater system. Some alternatives include domed risers, inlet structures, weirs, and openings in the planter box wall.

- **Planting soil** should be capable of supporting a healthy vegetative cover and should generally be between 12 and 36 inches deep. Planting soil should be approximately four inches deeper than the bottom of the largest root ball.

- A subsurface **gravel layer**, if used, should be at least six inches thick and constructed of clean gravel with a significant void space for runoff storage (typically 40 percent) and wrapped in geotextile (filter) fabric.

- If used, **underdrains** are typically small diameter (412 inches) perforated pipes in a clean gravel trench wrapped in geotextile fabric (or in the gravel layer). Underdrains should be double-walled and have a flow capacity capable of draining the planter box system in approximately 12 hours. They can daylight to the surface or connect to another stormwater system. A way to inspect and clean underdrains should be provided (via cleanouts, inlet, overflow structure, etc.)

- **Native trees and shrubs** may require irrigation during dryer summer months to remain healthy. Monitoring vegetation in planter boxes is critical to the health of the plants, as they may need supplemental watering, in addition to the water received from storms.

- **Many planter box styles and sizes** are used to improve site aesthetics and stormwater management. Incorporating smaller planter boxes over the site adds visual appeal and a greater surface area.

Design variations:

- **Contained boxes**

  Plants should be relatively self-sustaining, with little need for fertilizers or pesticides. Irrigation is optional, although plant viability should be maintained. Trees are encouraged and will receive added runoff reduction recognitions for the canopy that will extend beyond the planter walls. Structural elements of the planters should be stone, concrete, brick, wood, or other durable material. Treated wood that may leach out any toxic chemicals should not be used.

- **Infiltration**

  Allow captured runoff to drain out in three to four hours after a storm event. The sand/ gravel area width, depth, and length are to be determined by an engineer or a dry well may be required for complete onsite infiltration. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff. Minimum planter width is 30 inches; there is no minimum length or required shape. The structural elements of the planters should be stone, concrete, brick, or pressure-treated wood. Treated wood that may leach out any toxic chemicals should not be used.

- **Flow-through**

  Allow captured runoff to drain out in three to four hours after a storm event. Minimum planter width is 18 inches; there is no minimum length or required shape. Planters should be designed to receive less than 15,000 square-feet of impervious area runoff. Structural elements of the planters should be stone, concrete, brick, or pressure-treated wood. Treated wood that may leach out any toxic chemicals should not be used. The flow-through planter box is contained and, thus, not designed to drain into the ground near a building. Irrigation is optional, although plant viability should be maintained.

- The plants within the **perimeter planter boxes** are designed to accept stormwater runoff from adjacent impervious areas. Plants and vegetation absorb most of the water volume. Overflow gradually drains to the surface, which slows the peak rates.

- Review the materials list in Recommended Materials Appendix for recommended planter box specifications.

- **Landscaping requirements**

  The following quantities are recommended per 100 square feet of planter box area:

  - Four large shrubs/small trees in three-gallon containers or equivalent.
  - Six shrubs/large grass-like plants in one-gallon containers or equivalent
  - Ground cover plants (perennials/ annuals) one per 12 inches on center, triangular spacing. Minimum container: four-inch pot. Spacing may vary according to plant type.

- Plantings can include rushes, reeds, sedges, iris, dogwood, currants, and numerous other shrubs, trees, and herbs/grasses (Recommended Plant List for BMPS Appendix).

- Container planting requires that plants be **supplied with nutrients** that they would otherwise receive from being part of an ecosystem. Since they are cut off from these processes, they must be cared for accordingly.

- **Tree planting** in planters is encouraged where practical. Tree planting is also encouraged near planters.

- Generally, plants requiring **moist-wet conditions** are preferred for flow-through planters.

Stormwater Functions and Calculations

Volume reduction

If a planter box is designed to infiltrate, the volume reduction is a function of the area of the filter and the infiltration rate. There is generally less volume reduction for planter boxes that are not designed to infiltrate.

Infiltration Volume# = Bottom Area (ft^2) * Infiltration Rate (in/hr) * Drawdown time## (hr)

- For filters with infiltration only
- Not to exceed 3-4 hours

Peak rate mitigation

Planter boxes generally provide little, if any, peak rate reduction. However, if the planter box is designed to infiltrate, then a modest level of peak rate attenuation can be expected.

Water Quality Improvement

Planter boxes are considered a moderate stormwater treatment practice with the primary pollutant removal mechanism being filtration and settling. Less significant processes can include evaporation, infiltration (if applicable), transpiration, biological and microbiological uptake, and soil adsorption. The extent to which planter boxes remove pollutants in runoff is primarily a function of their design, configuration, plant species/ density, and soil type.

For planter boxes that are also designed to infiltrate, see the water quality summary in the Subsurface Infiltration Bed section of Infiltration Practices Fact Sheet, or in the other infiltration BMP sections. For manufactured planters, see the manufacturer's information, as well as findings from independent studies.

Construction Guidelines

Constructing or retrofitting planter boxes varies in difficulty at each site. Boxes may be ideal for inclusion in patio or walkway design and integrate easily with roof downspouts. In most cases, a landscape architect is essential, especially if the more complex infiltration and flow through variation is being constructed, and as the size/scale of the planter box grows larger.

1. Areas for planter boxes, especially the infiltration type, should be clearly marked before any site work begins to avoid soil disturbance and compaction during construction.

2. Planter boxes should generally be installed after the site is stabilized. Excessive sediment generated during construction can clog the planter and prevent or reduce the anticipated post-construction water quality benefits. Stabilize all contributing areas before runoff enters the filters.

3. Structures such as inlet boxes, reinforced concrete boxes, etc. should be installed in accordance with the guidance of the manufacturers or design engineer.

4. Infiltration planter boxes should be excavated in such a manner as to avoid compaction of the subbase. Structures may be set on a layer of clean, lightly compacted gravel (such as AASHTO #57).

5. Infiltration planter boxes should be underlain by a layer of permeable, nonwoven-geotextile.

6. Place underlying gravel/stone in minimum six-inch lifts and lightly compact. Place underdrain pipes in gravel.

7. Wrap and secure nonwoven geotextile to prevent gravel/stone from clogging with sediments.

8. Install planting soil per the recommendations of the landscape architect. Do not compact.

9. Install native vegetation (trees, shrubs, etc.) per the recommendations of the landscape architect.

Maintenance

Planter boxes are relatively high maintenance, as is the case with any containerized garden. Property owners should be especially prepared for maintaining the vegetation itself, which will vary depending upon planting. In many cases, planter boxes may need additional watering during extremely dry periods. Selection of planter box construction material is also important (e.g., masonry construction is easier to maintain than wood construction).

Generally speaking, stormwater facilities need an adequate amount of space for proper maintenance. The minimum required width for maintenance is typically eight feet and the maximum slope is 10 percent. If structural surfaces need to support maintenance vehicles, access routes should be constructed of gravel or other permeable paving surface.

Winter Considerations

Indiana's winter temperatures can go below freezing for a few months every year and surface filtration may not take place in the winter. Winterizing becomes an important issue in plant species selection, especially for larger, hardy or nearly hardy species intended to winter over. In these cases, planter boxes must be designed and dimensioned so that plantings are adequately protected.

Depending on the composition of the planting soil, it may hold water, freeze, and become impervious on the surface. Design options that allow directly for subsurface discharge into the underlying infiltration bed, if applicable, during cold weather may overcome this condition, but at the possible expense of surface filtration.

Cost

Costs for planter boxes are quite modest. However, based on unit cost of cubic foot or gallons of runoff being managed, costs tend to be rather high. Because of the extreme variability of design and construction, costs will range based on the goals of the designer. Smaller boxes with smaller-scale vegetation will be less expensive than larger boxes with more mature vegetation.

Designer/Reviewer Checklist for Planter Boxes

ITEM	Page No.	YES	NO	N/A	NOTES
For infiltration planters, was Soil Testing Infiltration Protocol (Soil Infiltration Testing Protocol Appendix) followed?*	--				
Appropriate areas of the site evaluated?	--				
Infiltration rates measured?	--				
For infiltration planters, was the Infiltration BMP followed?*	--				
Two-foot separation between the bed bottom and bedrock/ seasonally high water table?	--				
Soil permeability acceptable?	--				
If not, appropriate underdrain provided?	-				
Natural, uncompacted soils?	--				
Excavation in infiltration areas minimized?	--				
Drawdown time less than 48 hours?	--				
Erosion and sedimentation control?	--				
Adequately stable inflow point(s)?	4				
Positive overflow from system?	4				
Waterproofing provided, as necessary?	3				
Acceptable soil/growing medium specified? ➢ *Between 12 and 36 inches deep; 4 inches deeper than bottom of largest root ball*	4				
Gravel layer specified properly? ➢ *At least 6 inches thick*	4				
Underdrain positioned and sized? ➢ *Should be sized to drain within approximately 12 hours*	4				
Appropriate native plants selected?	3-5				
Feasible construction process and sequence?	--				
Maintenance accounted for and plan provided? ➢ *Minimum maintenance width = **8 ft**; max. width = **10 ft***	6,7				

➢ *Denotes Minimum Design Considerations*

** In general, the Protocol and Infiltration BMP should be followed as much as possible (although there is more flexibility for infiltration planters than for other BMPs such as pervious pavement and subsurface infiltration that rely almost entirely on infiltration).*

References

Stormwater Management Guidance Manual, Version 2.0. Office of Watersheds, Philadelphia, PA: Water Department. www.phillyriverinfo.org/programs/SubProgramMain.aspx?Id=StormwaterManual

Stormwater Management Manual, Revision 3. Portland, OR: Environmental Services, Clean River Works, September 2004. www.portlandonline.com

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BMP Fact Sheet

RIPARIAN BUFFER RESTORATION

A riparian buffer is the area of land that exists between low, aquatic areas such as rivers, streams, lakes, and wetlands, and higher, dry upland areas such as forests, farms, cities, and suburbs. Unaltered riparian buffers may exist as various types of floodplain forest or wetland ecosystems. The Michigan Natural Features Inventory (MNFI) has identified multiple types of distinct natural communities which may occur in Michigan's riparian areas, such as southern floodplain forest, southern wet meadow, emergent marsh, and hardwood conifer swamp.

Figure 1 Suburban riparian buffer - Edward Drain, West Bloomfield, MI
Source: JF New

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Yes	Peak Rate	Low/Med
Industrial	Yes	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Med/High
Highway/Road	Limited	TP	Med/High
Recreational	Yes	NO_3	Med/High
		Temperature	Med/High

Additional Considerations	
Cost	Low/Med
Maintenance	Low
Winter Performance	High

Key Design Features

Riparian buffers consist of three distinct zones:

- **Zone 1**: Streamside zone extends a minimum distance of 25 feet
- **Zone 2**: Middle zone extends immediately from the outer edge of Zone 1 for a minimum of 55 feet
- **Zone 3**: Outer zone extends a minimum of 20 feet immediately from outer edge of Zone 2

Site Factors

- Water table to bedrock depth: N/A
- Soils: Match vegetation to soils to maximize long-term viability of plantings
- Slope: N/A
- Potential hotspots: No
- Maximum drainage area: 5 to 20 times the buffer area

Benefits

- Water Quality
- Ecological and aesthetic value
- Low cost

Limitations

- Reduced volume and peak conrtol

Description and Function

A riparian buffer is a permanent restoration area of trees, shrubs, and herbaceous vegetation adjacent to a waterbody that serves to protect water quality and provide critical wildlife habitat. A riparian buffer can be designed to intercept surface runoff and subsurface flow from upland sources for the purpose of removing or buffering the effects of associated nutrients, sediment, organic matter, pesticides, or other pollutants prior to entry into surface waters and groundwater recharge areas.

The riparian buffer is most effective when used as a component of a sound land management system including nutrient management and runoff and sediment and erosion control practices. Use of this practice without other runoff and sediment and erosion control practices can result in adverse impacts on riparian buffer vegetation and hydraulics including high maintenance costs, the need for periodic replanting, and the flow of excess nutrients and sediment through the buffer.

Riparian buffer restoration areas consist of three distinct zones and can be designed to filter surface runoff as sheet flow and down-slope subsurface flow, which occurs as shallow groundwater. For the purposes of these buffer strips, shallow groundwater is defined as saturated conditions which occur near or within the root zone of trees and other woody vegetation and at relatively shallow depths where bacteria, low oxygen concentrations, and soil temperature contribute to denitrification. Riparian buffers are designed to encourage sheet flow and infiltration and impede concentrated flow.

Buffer widths and vegetation types

When developing specific widths for riparian buffers (**Figure 2**), keep site specific factors in mind, and use exact measurements as a guide for each site. Various buffer widths and vegetation types may be appropriate depending on:

- Project goals,
- The natural features of the river valley, wetlands, lake, and floodplain, and
- Wildlife habitat requirements.

Buffer averaging and minimum distances

Buffer ordinances that set specific and minimum buffer dimensions allow the local government to accept buffer averaging in order to accommodate variability in terrain or development plans. For example, a wetland normally entitled by ordinance to a 75-foot minimum buffer may be able to tolerate a 50-foot buffer over part of its margin if a wider buffer is provided along another part. This depends upon such issues as water flow, topography, habitat, and species needs, and other factors that can best be assessed on a case-by-case basis.

Port Townsend, Washington allows buffer averaging if the applicant demonstrates that the averaging will not adversely affect wetland functions and values, that the aggregate area within the buffer is not reduced, and that the buffer is not reduced in any location by more than 50 percent or to less than 25 feet.

Woodbury, Minnesota allows buffer averaging where averaging will provide additional protection to the wetland resource or to environmentally valuable adjacent uplands, provided that the total amount of buffer remains the same.

Source: Environmental Law Institute

Zone 1: Also termed the “streamside zone,” begins at the edge of the stream bank of the active channel and extends a minimum distance of 25 feet; this is measured horizontally on a line perpendicular to the water body.

Undisturbed vegetated area helps protect the physical and ecological integrity of the stream ecosystem. The vegetative target for the streamside zone is undisturbed native woody species with native plants forming canopy, understory, and duff layer where such forest does not grow naturally; then native vegetative cover appropriate for the area (such as grasses, forbs, or shrubs) is the vegetative target. (*HRWC Model Ordinance*, p. 8)

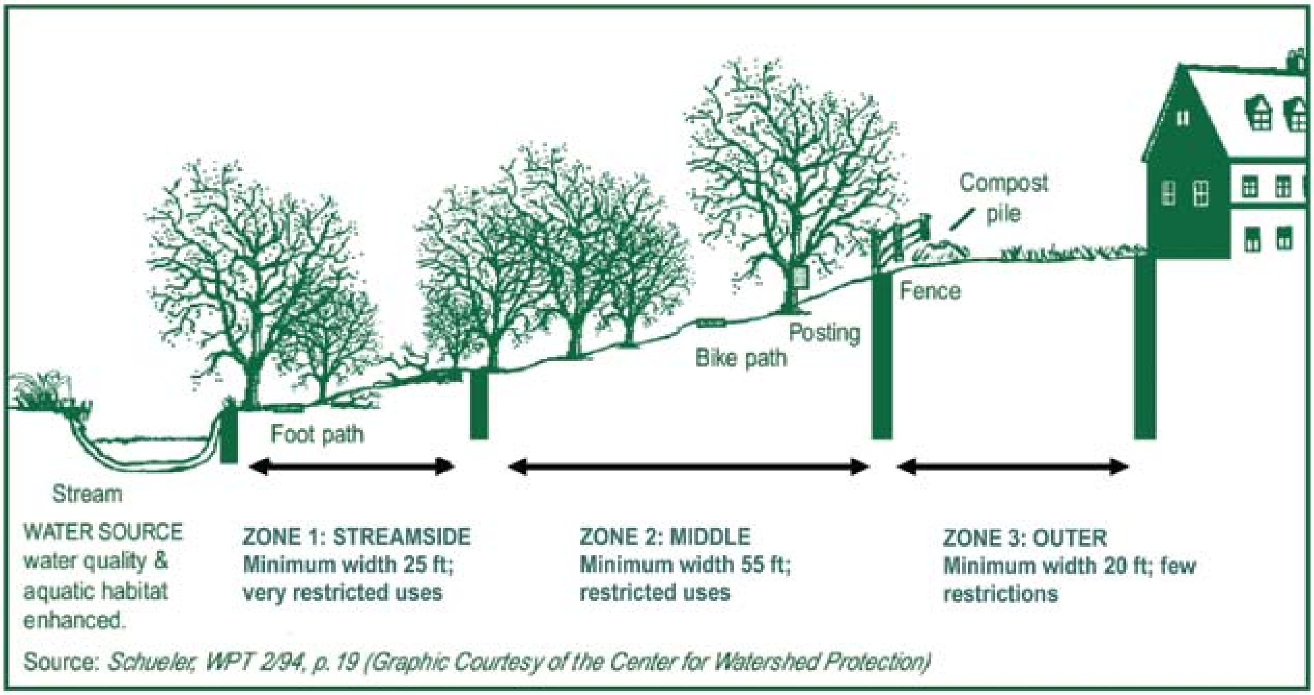

Figure 2 Source of a three-zone buffer
Source: Schueler, Watershed Protection Techniques, 1994 (Graphic courtesy of the Center for Watershed Protection)

Zone 2: Also termed the “middle zone,” extends immediately from the outer edge of Zone 1 for a minimum distance of 55 feet.

This managed area of native vegetation protects key components of the stream ecosystem and provides distance between upland development and the stream-side zone. The vegetative target for the middle zone is either undisturbed or managed native woody species or, in its absence, native vegetative cover of shrubs, grasses, or forbs. Undisturbed forest, as in Zone 1, is strongly encouraged to protect further water quality and the stream ecosystem. (*HRWC Model Ordinance* p. 8)

Zone 3: Also termed the “outer zone,” it extends a minimum of 20 feet immediately from outer edge of Zone 2.

This zone prevents encroachment into the riparian buffer area, filters runoff from adjacent land, and encourages sheet flow of runoff into the buffer. The vegetative target for the outer zone is native woody and herbaceous vegetation to increase the total width of the buffer. Native grasses and forbs are acceptable. (*HRWC Model Ordinance* p. 8)

To maximize wildlife habitat, restoration buffers should reflect the type of riparian vegetation that was found at the site before alteration. If water quality protection is the primary goal, greater emphasis may be placed on installing vegetation that enhances soil stability and absorbs pollutants. If the riparian area is very wet, wetland vegetation may be required.

In addition to installing vegetation, riparian buffer restoration may require physical restoration of soils, topography, or hydrology to achieve the desired result. Geographic factors such as the presence of steep slopes may necessitate an expanded buffer to achieve soil stability. If a river valley is very narrow, the buffer may be adjusted accordingly.

Applications

Riparian buffers are used adjacent to any wetland and bodies of water, such as lakes, streams, swales, and detention ponds. They are not typically applicable in upland areas where water bodies are not present. While riparian buffers provide significant water quality and ecological benefits, they have only very little benefit for volume control, unless they have some ability to trap and rapidly infiltrate water. Therefore, they should be used with other BMPs that will fulfill any volume control requirements.

Restoring riparian buffers can be applied in many settings:

1. Adjacent to permanent or intermittent streams,
2. At the margins of lakes or ponds,
3. At the margin of intermittent or permanently flooded, environmentally sensitive, open water wetlands,
4. On karst formations at the margin of sinkholes and other small groundwater recharge areas, and
5. Between manicured lawns, cultivated areas or hardscape and swales, streams or rivers to help dissipate and treat runoff and help stabilize the tops of channel banks.

Design Considerations

Restoring riparian buffer areas requires a plan to ensure long-term success. Below is a summary of the steps that groups, designers, engineers, or volunteers should undertake during the planning stages of a riparian buffer project.

1. **Confirm suitability for restoration**

   If stream banks are extensively eroded, consider an alternative location for preparing the riparian buffer, or consider stream bank restoration first. Rapidly eroding stream banks may undermine top of bank restoration efforts.

2. **Analyze site's physical conditions**

   Consider site specific factors to determine the particular width of the individual zones:

   - Watershed condition,
   - Slope,
   - Stream order,
   - Soil depth and erodibility,
   - Hydrology,
   - Seasonal high water table,
   - Floodplains,
   - Wetlands,
   - Streambanks,
   - Soil type,
   - Vegetation type, and
   - Stormwater systems.

3. **Analyze site's vegetative features** Existing vegetation at the restoration site should be examined to determine the overall strategy for buffer protection and establishment. Strategies will differ whether pre-restoration conditions are pasture, overgrown abandoned field, mid-succession forest, predominantly invasive vegetation, or another type of setting. An effort to inventory existing vegetation for protection and to determine type of pre-settlement vegetation should be made to guide efforts.

   - *Identify desirable species*: Native tree and shrub species that thrive in riparian habitats in Michigan should be used. These species should be identified in the restoration site and protected. Several native vines and shrubs can provide an effective ground cover when establishing the buffer, though they should be controlled to prevent herbaceous competition.

   - *Identify non-native and invasive species*: Consider using undesirable species for shading during buffer establishment. Control invasive plants prior to buffer planting may be necessary.

   - *Identify sensitive species*: Because riparian zones are rich in wildlife habitat and wetland plant species, be aware of any rare, threatened, or endangered plant or animal species. Be sure to protect sensitive species during riparian buffer restoration.

4. **Map the site**

   Prepare an existing conditions sketch of the site noting important features such as stream width, length, stream bank condition, adjacent land uses, stream activities, desired width of buffer, discharge pipes, obstructions, etc.

5. **Create a design that accomplishes multiple stakeholder objectives**

   Ideally, the three-zone system should be incorporated into the design to meet landowner, community, and watershed objectives:

   - *Landowner objectives*: Consider the current use of the buffer by the landowner, especially if the buffer will be protected by the landowner in perpetuity. How will the riparian buffer complement or conflict with existing and probable future uses of the property?

   - *Community objectives*: Consider linking the buffer to an existing or planned green infrastructure system, which may include trails, parks, preserves, and wildlife habitat buffers. How can a buffer help achieve local recreation and green space goals?

   - *Watershed objectives*: Examine the local watershed plan to identify goals related to riparian buffers. Have goals related to water quality been emphasized. Is wildlife habitat a primary concern?

6. **Design measures**

   The following elements represent a menu of design measures for riparian and natural resource protection that communities may choose to encourage or require developers to incorporate during the site plan review process.

   - *Stream size* – A majority of Indiana's stream system is comprised of small streams (first, second, and third order). It is important to reduce nutrient inputs to these streams.

   - *Availability of areas for continuous buffers* – Establishing continuous riparian buffers on the landscape should be given a priority over establishing fragmented buffers. Continuous buffers provide better shading and water quality protection as well as buffers for the wildlife movement.

   - *Degrees of degradation* – Urban streams have often been buried or piped as a result of previous development. Streams in areas without forestation may benefit the most from buffer restoration.

   - *Loading rate***s** - The potential for removing pollutants is generally highest where nutrient and sediment loading are the highest.

   - *Land uses* – Land uses adjacent to the riparian buffer may influence the required buffer width and vegetation types. While the three-zone riparian buffers described herein are ideal, the full widths of each zone may not always be feasible to establish, especially in urban areas.

   - *Habitats* – Establishing a buffer for habitat enhancement requires additional strategies beyond installing a buffer for increased water quality.

7. **Determine the appropriate buffer width**

   Riparian buffer areas need not have a fixed linear boundary, but may vary in shape, width, and vegetative type and character, depending on the goals of the restoration and the natural geography of the water body and riparian area. The desired function of the buffer (habitat, water quality, etc.) determines buffer width. Many factors, including slope, soil type, adjacent land uses, floodplain, vegetative type, and watershed condition influence the design of the buffer. A rule of thumb is "the bigger, the better." Buffer widths for water quality and habitat maintenance should generally be 35 to100 feet. Buffers less than 35 feet generally do not protect aquatic resources in the long term.

   - *Streamside buffers*

The minimum width of streamside buffer areas can be determined by a number of methods suitable to the geographic area.

Based on soil hydrologic groups as shown in the soil survey report, the width of Zone 2 should be increased to occupy any soils designated as Hydrologic Group D and those soils of Hydrologic Group C that are subject to frequent flooding. If soils of Hydrologic Groups A or B occur adjacent to intermittent or perennial streams, the combined width of Zones 1 and 2 may be limited to the 80-foot minimum.

Based on area, the width of Zone 2 should be increased to provide a combined width of Zones 1 and 2 equal to one-third of the slope distance from the stream bank to the top of the pollutant source area. The effect is to create a buffer strip between field and stream that occupies approximately one-third of the source area.

- Pond and lake-side buffers

The area of pond or lake-side buffer strips should be at least one-fifth the drainage area of the cropland and pastureland source area. The width of the buffer strip is determined by creating a uniform width buffer of the required area between field and pond. Hydrologic group determining width remains the same as for streamside buffers. Minimum widths apply in all cases.

8. **Vegetation selection**

Zone 1 and 2 vegetation should consist of native streamside species on soils of Hydrologic Groups C and D and native upland species on soils of Hydrologic Groups A and B.

Deciduous species are important in Zone 2 due to the production of carbon leachate from leaf litter, which drives bacterial processes that remove nitrogen and sequester nutrients in growth processes. In warmer climates, evergreens are also important due to the potential for nutrient uptake during the winter months. In both cases, a variety of species is important to meet the habitat needs of insects important to the aquatic food chain.

Zone 3 vegetation should consist of perennial grasses and forbs. Species recommendations for restoring riparian buffers depend on the geographic location of the buffer. Suggested species lists can be developed in collaboration with appropriate state and federal forestry agencies, the Natural Resources Conservation Service, and the USDA Fish and Wildlife Service. Species lists should include trees, shrubs, grasses, legumes, and forbs, as well as site preparation techniques. Please refer to the plant list in Recommended Plant List for BMPs Appendix for a recommended list of native trees and shrubs.

Green Development Standards

In 2007, the U.S. Green Building Council finalized pilot rating standards for the new Leadership in Energy and Environmental Design – Neighborhood Development (LEED –ND) certification program, which set standards for environmentally superior development practices. Developers can earn certification credit for preserving a buffer around all wetlands and water bodies located on site in perpetuity. Local governments that adopt buffer ordinances encourage LEED-ND developments.

Source: Environmental Law Institute

The choice of planting stock (seeds, container seedling, bare-root seedlings, plugs, etc.) is often determined by cost. Larger plants usually cost more, though will generally establish more rapidly.

Many factors threaten the long-term viability of riparian plant protection or establishment. With proper foresight, these problems can be minimized. The following items should be considered during the planning stage:

- Deer control
    - Look for signs of high deer densities, including an overgrazed understory with a browse line five to six feet above the ground.
    - Select plants that deer do not prefer (e.g., paper birch, beech, common elderberry)
    - Apply homemade deer repellants
    - Install tree shelters
- Tree shelters
    - Tree shelters, such as plastic tubes that fit over newly planted trees, are extremely successful in protecting seedlings. They may be secured with a wooden stake and netting may be placed over top of the tree tube. They are recommended for riparian plantings where deer or human intrusion may be a problem. Tree shelters should be removed two to three years after the saplings emerge. ° Tree shelters protect trees from accidental strikes from mowing or trimming.
    - Tree shelters create favorable microclimate for seedlings.
    - Tree shelters should be inspected at least four times per year. The following maintenance should be performed as necessary:
        - Repair broken stakes
        - Tighten stake lines
        - Straighten leaning tubes
        - Clean debris from tube
        - Remove netting as tree grows
        - Remove when tree trunk is approximately two inches wide
- Stream buffer fencing
    - Farm animals may cause great damage to stream banks. Consider permanent fencing such as high-tensile smooth wire fencing or barbed fencing.
    - The least expensive fencing is eight-foot plastic fencing, which is also effective against deer and is easily repaired
- Vegetation
    - Consider using plants that are able to survive frequent or prolonged flooding conditions. Plant trees that can withstand high water table conditions.
    - Soil disturbance can allow for unanticipated infestation by invasive plants.
- Accidental or purposeful destruction by landowners
    - Signage, posts, fencing, boulders, etc., may be required to alert adjacent landowners to the location, purpose, and management aims of riparian buffers. This is particularly important where actively managed landscaped areas abut native plant buffers. Signs that stress no mow/no pesticide and fertilizer zones may need to be in several languages, e.g., English and Spanish.

9. **Restoration design within your budget** The planting design (density and types) must ultimately conform to the financial constraints of the project. See discussion below for estimating direct costs of planting and maintenance.

10. **Draw a restoration planting plan**

- Planting layout: The planting plan should be based on the plant types and density. The plan must show the site with areas denoted for trees and shrub species and plant spacing and buffer width.
- Planting density: Trees should be planted at a density sufficient to provide 320 trees per

Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)	Spacing (feet)	Trees (number)
2x2	10,890	7x9	691	12x15	242
3x3	4,840	7x10	622	12x18	202
4x4	2,722	7x12	519	12x20	182
4x5	2,178	7x15	415	12x25	145
4x6	1,815	8x8	681	13x13	258
4x7	1,556	8x9	605	13x15	223
4x8	1,361	8x10	544	13x20	168
4x9	1,210	8x12	454	13x25	134
4x10	1,089	8x15	363	14x14	222
5x5	1,742	8x25	218	14x15	207
5x6	1,452	9x9	538	14x20	156
5x7	1,245	9x10	484	14x25	124
5x8	1,089	9x12	403	15x15	194
5x9	968	9x15	323	15x20	145
5x10	871	10x10	436	15x25	116
6x6	1,210	10x12	363	16x16	170
6x7	1,037	10x15	290	16x20	136
6x8	908	10x18	242	16x25	109
6x9	807	11x11	360	18x18	134
6x10	726	11x12	330	18x20	121
6x12	605	11x15	264	18x25	97
6x15	484	11x20	198	20x20	109
7x7	889	11x25	158	20x25	87
7x8	778	12x12	302	25x25	70

Table 1 Tree spacing per acre

acre at maturity. To achieve this density, approximately 436 (10 x 10 feet spacing) to 681 (8 x 8 feet spacing) trees per acre should be planted initially. Some rules of thumb for tree spacing and density based on plant size at installation follow:

- Seedlings 6 to 10 feet spacing (~700 seedlings/acre)
- Bare root stock 4 to 16 feet spacing (~200 plants/acre)
- Larger & Container 16 to 18 feet spacing (~150 plants/acre)

Formula for estimating number of trees and shrubs:

Number of Plants = length x width of buffer (feet) / 50 ft^2

This formula assumes each tree will occupy an average of 50 square feet, random placement of plants approximately 10 feet apart, and a mortality rate of up to 40 percent.

Alternatively, the table below can be used to estimate the number of trees per acre needed for various methods of spacing.

11. **Prepare site for restoration** Existing site conditions determine the degree of preparation needed prior to planting. Invasive plant infestation and vegetative competition are variable and must be considered in the planning stages. Site preparation should begin in the fall prior to planting. Determine whether the use of herbicides is necessary.

    Mark the site with flags, or marking paint, so that the plants are placed in the correct locations.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the local County Surveyor's Office is highly recommended.

Stormwater Functions and Calculations

Volume and peak rate

Restoration of the riparian buffer will lower runoff volume and peak rates through lowering the runoff coefficient (i.e., curve number). Designers can receive runoff reduction recognition based on the square feet of trees or shrubs being added. Proposed trees and shrubs to be planted under the requirements of these BMPs can be assigned a curve number (CN) reflecting a woodlot in "good" condition associated with the pre-development underlying soil layer for an area of 200 square feet per tree or the estimated tree canopy, whichever is greater. For shrubs, calculate based an area of 25 square feet per shrub. Calculation methodology to account for this BMP is provided in the LID Approach discussion of the Post-Construction Stormwater Management Chapter of Technical Standards.

Water quality improvement

Water quality benefits of restoring riparian buffers are medium to high. The amount of benefit is based on flow characteristics and nutrient, sediment, and pollutant loadings of the runoff as well as the length, slope, type, and density of vegetation in the riparian buffer.

Runoff entering Zone 3 filters sediment, begins nutrient uptake, and converts concentrated flow to uniform, shallow sheet flow. Zone 2 provides contact time and carbon energy sources in which buffering processes can take place. It also provides long-term sequestering of nutrients. Zone 1 provides additional soil and water contact area to further facilitate nutrient buffering processes, provides shade to moderate and stabilize water temperature, and encourages production of beneficial algae.

Maintenance

An effective riparian buffer restoration project should include stewardship guidelines to manage and maintain the site in perpetuity. The most critical period of riparian buffer establishment is canopy closure, which is typically the first three to five years after saplings are planted. Buffer boundaries should be well defined with clear signs or markers. During this time, the riparian buffer should be monitored four times annually (February, May, August, and November are recommended) and inspected after any severe storm. Maintenance measures that should be performed regularly include:

1. **Watering**

   - Plantings need deep, regular watering during the first growing season, either natural watering via rainfall, or planned watering via caretaker.
   - Planting in the fall increases the likelihood of sufficient rain during planting establishment.

2. **Mulching**

   - Mulch provides moisture retention in the root zone of plantings, or potentially impacted vegetation from construction, moderate soil temperature, and some weed suppression.

   - Use coarse, organic mulch that is slow to decompose in order to reduce the need for repeat application.

   - Apply a two to four-inch layer, leaving air space around tree trunk to prevent fungus growth.

   - Use a combination of woodchips, leaves, and twigs that have been stockpiled for six months to a year.

3. **Weed and invasive plan control**

   - Invasive plants can overrun even a well-designed planting. It is essential that there is a plan in place to monitor and remove invasive vegetation as the planting matures. Use the Nature Conservancy's Global Invasive Species Team Web page as a resource for management techniques. (http://tncweeds.ucdavis.edu/esadocs.html) Non-chemical weed control methods are preferred since chemicals can easily be washed into the stream.

- *Herbicides*

  Using herbicides is a short-term maintenance technique (two to three years) that is generally considered less expensive and more flexible than mowing and will result in a quicker establishment of the buffer. Consider and evaluate the proximity of herbicide use to water features.

- *Mowing*

  Mowing controls the height of the existing grasses, yet increases nutrient uptake. Therefore, competition for nutrients will persist until the canopy closure shades out lower layers of growth. A planting layout similar to a grid format will facilitate ease of mowing, but will yield an unnaturally spaced community. Mowing may result in strikes to tree trunks unless protective measures are used. Mowing should occur twice each growing season. Mower height should be set between eight and12 inches.

- *Weed mats*

  Weed mats are geo-textile fabrics used to suppress weed growth around newly planted vegetation by blocking sunlight and preventing seed deposition. Weed mats are installed after planting, and should be removed once the trees have developed a canopy that will naturally shade out weeds.

4. **Stable debris**

   As Zone 1 reaches 60 years of age or is hit with pests or disease, it will begin to produce large debris. Large debris, such as logs, create small dams which trap and hold debris for processing by aquatic insects, thus adding energy to the stream ecosystem, strengthening the food chain, and improving aquatic habitat. Wherever possible, stable debris should be conserved.

   - Where debris dams must be removed, try to retain useful, stable portions which can provide storage. (A state permit may be required). For guidance on evaluating debris impacts on streams and methods for managing debris jams, refer to the "Primer on Large Woody Debris Management" developed by the City of Rochester Hills (see References).

   Deposit removed material a sufficient distance from the stream so that it will not be refloated by high water.

5. **Resources for assistance** Local land conservancies are excellent resources when considering the long-term stewardship of the area. If a site has critical value, a local conservancy may be interested in holding a conservation easement on the area, or may be able to provide stewardship services and assistance. Wild Ones (www.for-wild.org/) is a national organization with local chapters which may also provide stewardship resources.

Winter Considerations

Volume reduction, peak rate mitigation, and water quality benefits are not as pronounced in winter months compared to the rest of the year in riparian buffers because infiltration rates are generally lower during prolonged cold weather periods. In addition, evapotranspiration rates are lower in winter months because most vegetation is dormant. However, riparian buffers still provide stormwater management benefits even in winter.

Cost

Installing a riparian buffer involves site preparation, planting, second year reinforcement planting, and additional maintenance. Costs may fluctuate based on numerous variables including whether or not volunteer labor is used, and whether plantings and other supplies are donated or provided at a reduced cost. The following table presents an estimate of typical costs for riparian buffer restoration.

Criteria to receive runoff reduction recognition for Riparian Buffer Restoration

To receive runoff reduction recognition for riparian buffer restoration under a location regulation, the following criteria must be met:

- ☐ Area is protected by having the limits of disturbance clearly shown on all construction drawings and delineated in the field. 3
- ☐ Area to receive runoff reduction recognition for trees is 200 square feet per tree or the estimated tree canopy, whichever is greater.
- ☐ Area to receive runoff reduction recognition for shrubs is 25 square feet per shrub.
- ☐ Area is located on the development project.
- ☐ Area has a maintenance plan that includes weeding and watering requirements from initial installation throughout ongoing maintenance.

Designer/Reviewer Checklist for Riparian Buffer Restoration

ITEM	Page No.	YES	NO	N/A	NOTES
Avoidance of stormwater concentration as much as practical?	--				
Appropriate buffer widths designed? ➢ *Ideal minimum widths* o *Zone 1:* ***25 feet*** o *Zone 2:* ***55 feet*** o *Zone 3:* ***20 feet*** o *Water Quality/Habitat Maintenance:* ***35-100 feet*** ➢ *Various Buffer widths and vegetation types may be appropriate depending on:* o *Project Goals* o *Natural features of river valley, wetlands, lake, and floodplain* o *Wildlife Habitat Requirements*	1-3, 5,6				
Soil erodibility considered?	4				
Slope considered and appropriate?	--				
Appropriate vegetation selected based on soils, hydrology, and ecoregion?	6,7				
Appropriate vegetation selected based on budget and aesthetics?	--				
Appropriate plant spacing designed?	7,8				
Appropriate balance of woody to herbaceous species?	6				
Seasonality of planting/construction considered?	8				
Erosion and sedimentation control provided?	--				
Maintenance accounted for and plan provided?	9,10				

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

SOIL RESTORATION

Soil is a key ingredient in effective stormwater and water quality management, making proper care of soils a key component of low impact development.

Soil restoration is a technique used to enhance and restore soils by physical treatment and/or mixture with additives – such as compost – in areas where soil has been compacted. Soil media restoration increases the water retention capacity of soil, reduces erosion, improves soil structure, immobilizes and degrades pollutants (depending on soil media makeup), supplies nutrients to plants, and provides organic matter. Soil restoration is also used to reestablish the soil's long term capacity for infiltration and to enhance the vitality of the soil as it hosts all manner of microbes and plant root systems in complex, symbiotic relationships.

Table 1 Soil restoration, Colerain Park, OH (Colerain Township)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Medium
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Yes	Peak Rate	Medium
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	High*
Highway/Road	Yes	TP	High*
Recreational	Yes	NO_3	Medium
		Temperature	Medium

Additional Considerations	
Cost	Medium
Maintenance	Low
Winter Performance	High

Key Design Features

- Follow nonstructural BMP to minimize soil compaction
- Evaluate existing soil conditions using methods referenced in Soil Infiltration Testing Protocol (found in AppendixD4) before creating a soil restoration strategy
- Soil media used in restoration is either organic or inorganic (man-made) and is mixed into existing soil

Benefits

- Widely applicable
- Relatively low cost
- Additional benefits such as improved plant health and reduced erosion

Limitations

- Relatively limited stormwater benefits on a unit area basis

*Newly amended soils are susceptible to erosion and release of TSS and phosphorus until stabilized with mulch, erosion blanket, sod, or some other covering.

Description and Function

Soil can be restored after construction to partially recondition that which has been degraded by compaction. Bulk density field tests measure soil compaction and can be used to help determine if soil restoration is necessary. Restoring the soil improves its structure and function, increases infiltration potential, and supports healthy vegetative communities.

A healthy soil (**Figure 1**) provides a number of vital functions including water storage and nutrient storage, regulate the flow of water, and immobilize and degrade pollutants. Healthy soil contains a diverse community of beneficial microorganisms, a sufficient amount of plant nutrients (nitrogen and phosphorous), some trace elements (e.g., calcium and magnesium), and organic matter (generally 5 to 10 percent). Healthy soil typically has a neutral or slightly acidic pH and good structure which includes various sizes of pores to support water movement, oxygenation, and a variety of other soil processes.

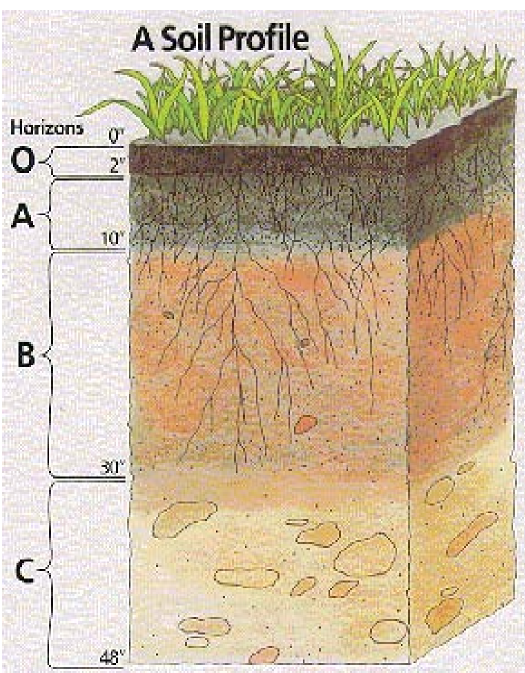

Figure 1 Healthy Soil Profile
Source: USDA NRCS

Caring for soil is also a critical component of water management, especially during development activities, such as construction grading, which often result in erosion, sedimentation, and soil compaction. Proper protection and restoration of soil is a critical BMP to combat these issues. Soil restoration prevents and controls erosion by enhancing the soil surface to prevent the initial detachment and transport of soil particles.

Soil compaction

Soil compaction is the enemy of water quality protection. Soil compaction occurs when soil particles are pressed together, reducing the pore space necessary to allow for the movement of air and water throughout the soil (**Figure 2**). This decrease in porosity causes an increase in bulk density (weight of solids per unit volume of soil). The greater the bulk density of the soil, the lower the infiltration and therefore, the larger the volume of runoff.

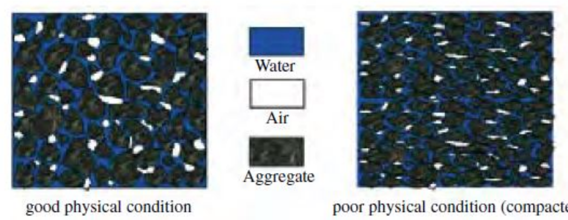

Figure 2 Compacted soil constrains movement of air and water
Source: USDA NRCS

Compaction limits vegetative root growth, restricting the health of plants as well as the biological diversity of the soil. Compaction also affects the infiltrating and water quality capacity of soils. Soil compaction can lead to increased erosion and stormwater runoff, low infiltration rates, increased flooding, and decreased water quality from polluted runoff. After compaction, a typical soil has strength of about 6,000 kilopascals (kPa), while studies have shown that root growth is not possible beyond 3,000 kPa. There are two types of compaction, minor and major, each of which requires a particular restoration technique(s) or method:

- **Minor compaction** – Surface compaction within 8-12 inches due to contact pressure and axle load greater than 20 tons can compact through root zone up to one-foot deep. Soil restoration activities can include: subsoiling, organic matter amendment, and native landscaping. Tilling/scarifying is an option as long as it is deep enough (i.e., 8-12 inches) and the right equipment is used (should not be performed with common tillage tools such as a disk or chisel plow because they are too shallow and can compact the soil just beneath the tillage depth).

- **Major compaction** – Deep compaction, contact pressure and axle load greater than 20 tons can compact up to two-feet deep (usually large areas are compacted to increase strength for paving and foundation with overlap to "lawn" areas). Soil restoration activities can include: deep tillage, organic matter amendment, and native landscaping.

To evaluate the level of compaction in soils, bulk density field tests are conducted. **Table 2** shows the ideal bulk densities for various textures of soils.

Amending media

Compacted soil can be amended by first tilling the soil, breaking apart the compaction, and then applying various soil media. For minor soil compaction, six inches of soil media (18.5 cubic yards per 1,000 square feet of soil) should be applied, and then tilled into the existing soil up to eight inches. For major soil compaction, 10 inches of soil media (31 cubic yards per 1,000 square feet of soil) should be applied and then tilled into the existing soil up to 20 inches.

Soil media used for amendment may be comprised of either organic or inorganic material. Organic media can increase soil organic matter content, which improves soil aeration, water infiltration, water and nutrient holding capacity, and is an important energy source for bacteria, fungi, and earthworms.

Organic media:

- Compost,*
- Aged manure,*
- Biosolids* (must be a Grade 1 biosolid),
- Sawdust, (can tie up nitrogen and cause deficiency in plants),
- Wood ash (can be high in pH or salt),
- Wood chips (can tie up nitrogen and cause deficiency in plants),
- Grass clippings,
- Straw, and
- Sphagnum peat (low pH;).

**Materials containing animal wastes can cause phosphorus to be exported from the amended soils.*

Inorganic media:

- Vermiculite,
- Perlite,
- Pea gravel, and
- Sand.

Soil Texture	Ideal Bulk densities, g/cm3	Bulk densities that may affect root growth, g/cm3	Bulk densities that restrict root growth, g/cm3
Sands, loamy sands	<1.60	1.69	1.8
Sandy loams, loams	<1.40	1.63	1.8
Sandy clay loams, loams, clay loams	<1.40	1.6	1.75
Silt, silt loams	<1.30	1.6	1.75
Silt loams, silty clay loams	<1.10	1.55	1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	1.58
Clays (>45% clay)	<1.10	1.39	1.47

Table 2 Bulk Densities for Soil Textures
Source: Protecting Urban Soil Quality, USDA-NRCS

Applications

Soil restoration can occur anywhere to alleviate soil compaction. It can be specifically addressed in the following examples:

- **New development (residential, commercial, industrial)** – Heavily compacted soils can be restored prior to lawn establishment and/or landscaping to increase the porosity of the soils and aid in plant establishment.

- **Detention basin retrofits** – The inside face of detention basins are usually heavily compacted, and tilling the soil mantle will encourage infiltration to take place and aid in establishing vegetative cover.

- **Golf courses** – Using compost as part of landscaping upkeep on the greens has been shown to alleviate soil compaction, erosion, and turf disease problems.

Design Considerations

1. Tilling the soil (also referred to as scarification, ripping, or subsoiling)

   a. Effective when performed on dry soils.

   b. Should be performed where subsoil has become compacted by equipment operation, dried out, and crusted, or where necessary to obliterate erosion rills.

   c. Should be performed using a solid-shank ripper and to a depth of 20 inches, (eight inches for minor compaction).

   d. Should be performed before amending media is applied and after any excavation is completed.

   e. Should not be performed within the drip line of any existing trees, over underground utility installations within 30 inches of the surface, where trenching/drainage lines are installed, where compaction is by design, and on inaccessible slopes.

   f. The final pass should be parallel to slope contours to reduce runoff and erosion.

   g. Tilled areas should be loosened to less than 1,400 kPa (200 psi) to a depth of 20 inches below final topsoil grade.

   h. The subsoil should be in a loose, friable condition to a depth of 20 inches below final topsoil grade and there should be no erosion rills or washouts in the subsoil surface exceeding three inches in depth.

   i. Tilling should form a two-directional grid. Channels should be created by a commercially available, multi-shanked, parallelogram implement (solid-shank ripper), capable of exerting a penetration force necessary for the site.

   j. No disc cultivators, chisel plows, or spring-loaded equipment should be used for tilling. The grid channels should be spaced a minimum of 12 inches to a maximum of 36 inches apart, depending on equipment, site conditions, and the soil management plan.

   k. The channel depth should be a minimum of 20 inches or as specified in the soil management plan. If soils are saturated, delay operations until the soil, except for clay, will not hold a ball when squeezed.

   l. Only one pass should be performed on erodible slopes greater than one vertical to three horizontal.

2. Applying soil media for amendment

   a. Soil media should not be used on slopes greater than 30 percent. In these areas, deep-rooted vegetation can be used to increase stability.

   b. Soil restoration should not take place within the critical root zone of a tree to avoid damaging the root system. (Where one inch of tree trunk diameter at breast height (DBH) is equal to one foot of soil area on the ground away from the tree trunk.)

c. Onsite soils with an organic content of at least five percent can be stockpiled and reused to amend compacted soils, saving costs. Note: These soils must be properly stockpiled to maintain organic content.

d. Soils should generally be amended at about a 2:1 ratio of native soil to media. If a proprietary product is used, follow the manufacturer's instructions for the mixing and application rate.

e. Add six inches compost or other media and till up to eight inches for minor compaction. (Six inches of compost equates to 18.5 yd^3 per 1,000 ft^2 of soil.)

f. Add 10 inches compost or other amendment and till up to 20 inches for major compaction. 10 inches of compost equates to approx. 30.9 yd^3 per 1,000 ft^2.

g. Compost can be amended with bulking agents, such as aged crumb rubber from used tires, or wood chips. This can be a cost-effective alternative that reuses waste materials while increasing permeability of the soil.

Stormwater Functions and Calculations

Volume and peak rate reduction

Restored soils result in increased infiltration, decreased volume of runoff, and significantly delayed runoff.

Soil restoration will lower runoff volume and peak rates by lowering the runoff coefficient (i.e., curve number). Designers can receive runoff reduction recognition based on areas (acres) complying with the requirements of these BMPs. These areas can be assigned a curve number (CN) reflecting the pre-development hydrologic soil group of underlying soil layer type instead of what is required for other disturbed pervious areas. The LID Approach discussion of Post-Construction Stormwater Management Chapter of Technical Standards show how to calculate the runoff reduction recognition for this BMP.

Water quality improvement

Although either organic or inorganic materials may be used as soil media, only organic matter can improve water quality by increasing the nutrient holding capacity of soils. Soils rich in organic matter contain microorganisms that immobilize or degrade pollutants. See LID Approach discussion of Post-Construction Stormwater Management Chapter of Technical Standards for information on how to calculate the volume of runoff that needs treatment for water quality improvement.

Organic materials that include fecal matter or animal renderings should not be used where water may infiltrate though the soil and carry nutrients, primarily phosphorus, to surface waters (Hunt and Lord, 2006).

Maintenance

Soil restoration may need to be repeated over time, due to compaction by use and/or settling. Taking soil core samples will help to determine the degree of soil compaction and if additional media application is necessary.

Winter Considerations

Since soil restoration is performed in conjunction with plantings, this BMP should be undertaken in spring or autumn and during dry weather, so that plantings can establish.

Cost

Cost information has been compiled by Cahill Associates and reflects 2007 conditions:

- Tilling costs range from $800/acre to $1,000/acre

- Compost costs range from $860/acre to $1,000/acre. Costs of other soil media would vary greatly depending on their individual material costs and the amounts used.

Criteria to receive runoff reduction recognition for Soil Restoration

To receive runoff reduction recognition for soil restoration under a location regulation, the following criteria must be met:

- ☐ Area is clearly shown on all construction drawings and delineated in the field.
- ☐ Tilling the soil is required if subsoil is compacted; needs to occur before amending media is applied.
- ☐ Area is not located on slopes greater than 30 percent.
- ☐ Area is not within the critical root zone of any tree.
- ☐ Amendment consists of six inches for minor compaction; 10 inches of amendment for major compaction.
- ☐ Area is located on the development project.

Designer/Reviewer Checklist for Soil Restoration

Type of soil amendment(s) proposed: ____

Amount of amendments(s) to be used: ____

ITEM	Page No.	YES	NO	N/A	NOTES
Appropriate soil amendment(s) for the site conditions? ➢ *Do not use soil media on slopes > 30%*	3,4				
Adequate amount of amendment materials?	3				
Bulk density/degree of compaction considered?	2,3				
Appropriate decompaction techniques and equipment?	4				
Appropriate construction sequencing?	--				
Sensitive areas (e.g., near existing trees, shallow utilities, and steep slopes) accounted for?	4				
Appropriate vegetation selected?	--				
Seasonality of planting/construction considered?	5				
Erosion and sedimentation control provided?	--				
Maintenance accounted for and plan provided?	5				

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

VEGETATED FILTER STRIP

A vegetated filter strip is a permanent, maintained strip of vegetation designed to slow runoff velocities and filter out sediment and other pollutants from urban stormwater. Filter strips require the presence of sheet flow across the strip, which can be achieved through the use of level spreaders. Frequently, filter strips are designed where runoff is directed from a parking lot into a stone trench, a grass strip, and a longer naturally vegetative strip.

Figure 1 Gravel trench directing water from the parking lot to a vegetated filter strip in Springfield, OR (Springfield Environmental Services Division)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	Low
Commercial	Yes	Groundwater Recharge	Low
Ultra Urban	Limited*	Peak Rate	Low
Industrial	Limited*	**Stormwater Quality Functions**	
Retrofit	Yes	TSS	Med/High
Highway/Road	Yes	TP	Med/High
Recreational	Yes	NO_3	Med/High
		Temperature	Med/High

* According to site characteristics

Additional Considerations	
Cost	Low
Maintenance	Low/Medium Varies dependent on type of vegetation
Winter Performance	High

Variations

- Turf grasses
- Prairie grasses, shrubs, and groundcover vegetation, including trees
- Indigenous woods and dense vegetation

Key Design Features

- Use with level spreaders to promote sheet flow across strips
- Longitudinal slope from 1-6 percent
- Maintain dense vegetation

Site Factors

- Water table to bedrock depth: N/A
- Soils: N/A for permeability
- Slope: 2-5 percent preferred (1-10 percent if soils/vegetation allow)
- Potential hotspots: Yes with special design considerations
- Max. drainage area: 100 feet impervious or 150 feet pervious up gradient

Benefits

- Low cost
- Good water quality performance
- Aesthetic and habitat benefits

Limitations

- Generally should be coupled with other BMPs for comprehensive stormwater management

Description and Function

Filter strips (**Figure 2**) are gently sloping areas that combine a grass strip and dense vegetation to filter, slow, and infiltrate sheet flowing stormwater. Filter strips are best used to treat runoff from roads and highways, roof downspouts, small parking lots, and other impervious surfaces. They are generally not recommended as stand-alone features, but as pretreatment systems for other BMPs, such as infiltration trenches or bioretention areas. Therefore, filter strips generally should be combined with other BMPs as part of a treatment train so that water quality and quantity benefits are sufficient to meet recommended site design criteria.

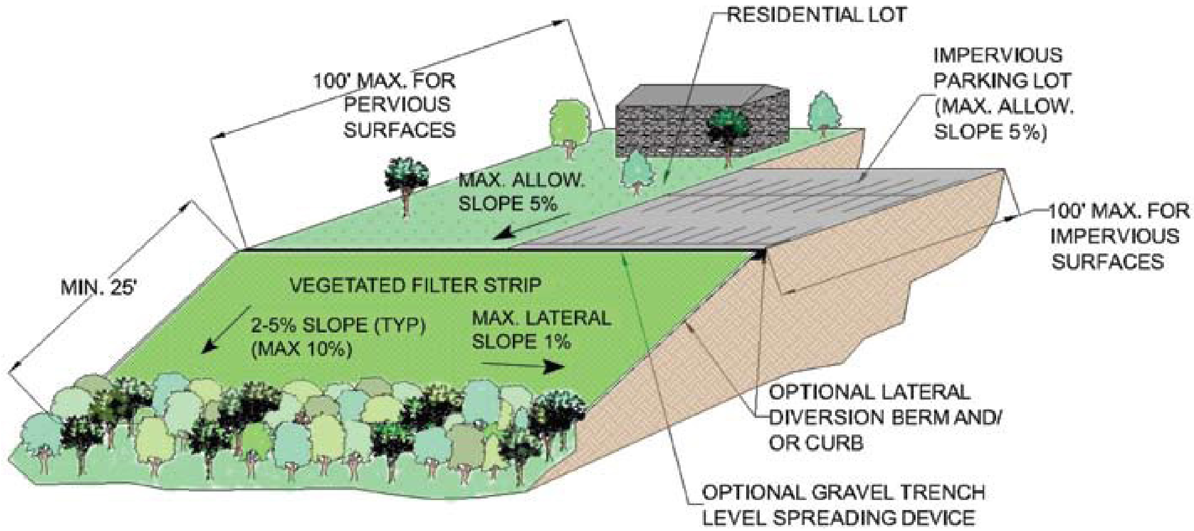

Figure 2 Diagram showing elements of a vegetated filter strip

Maintaining a dense growth pattern that includes turf-forming grasses and vegetation on a filter strip is critical for maximizing pollutant removal efficiency and erosion prevention.

The grass portion of the filter strip provides a pretreatment of the stormwater before it reaches the densely vegetated, or wooded area. In addition, a stone drop can be located at the edge of the impervious surface to prevent sediment from depositing at this critical entry point.

In addition to a stone drop, a pervious berm can reduce runoff velocity and increase volume reduction by providing a temporary, shallow ponded area for the runoff. The berm should have a height of not more than six to 12 inches and be constructed of sand, gravel, and sandy loam to encourage growth of a vegetative cover.

An outlet pipe(s) or an overflow weir may be provided and sized to ensure that the area drains within 24 hours or to allow larger storm events to pass. The berm must be erosion resistant under the full range of storm events. Likewise, the ponded area should be planted with vegetation that is resistant to frequent inundation.

Filter strips are primarily designed to reduce total suspended solids (TSS) levels. However, pollutants such as hydrocarbons, heavy metals, and nutrients may also be reduced. Pollutant removal mechanisms include sedimentation, filtration, absorption, infiltration, biological uptake, and microbial activity. Depending on soil properties, vegetative cover type, slope, and length of the filter strip, a reduction in runoff volume may also be achieved by infiltration.

Applications

Vegetated filter strips can be used in a wide variety of applications from residential/commercial developments to industrial sites and even transportation projects where the required space is available. Lack of available space limits use in ultra urban areas and some redevelopment projects.

Design Considerations

1. The design of vegetated filter strips is determined by existing drainage area conditions including drainage area size, length, and slope. In addition, the filter strip soil groups, proposed cover type, and slope needs to be determined. This information is used to determine the length of the filter strip using the appropriate graph (Figures 5 through 9).

2. Level spreading devices are highly recommended to provide uniform sheet flow conditions at the interface of the adjacent site area and the filter strip (see Level Spreader BMP Fact Sheet for detailed information). Concentrated flows should not be allowed to flow onto filter strips, as they can lead to erosion and, thus, failure of the system. Examples of level spreaders include:

   a. A gravel-filled trench (**Figure 3**), installed along the entire up-gradient edge of the strip. The gravel in the trenches may range from pea gravel (ASTM D 448 size no. 6, 1/8" to 3/8") for most cases to shoulder ballast for roadways. Trenches are typically 12" wide, 24-36" deep, and lined with a nonwoven geotextile. When placed directly adjacent to an impervious surface, a drop (between the pavement edge and the trench) of 1-2" is recommended, in order to inhibit the formation of the initial deposition barrier.

   b. A concrete curb stop with cutouts (**Figure 4**) can be used to provide uniform sheet flow across a vegetated filter strip.

   c. Concrete sill (or lip).

   d. An earthen berm (**Figure 5)** with optional perforated pipe.

3. Where possible, natural spreader designs and materials, such as earthen berms, are generally recommended, though they can be more susceptible to failure due to irregularities in berm elevation and density of vegetation. When it is desired to treat runoff from roofs or curbed impervious areas, a more structural approach, such as a gravel trench, is required. In this case, runoff should be directly conveyed, via pipe from downspout or inlet, into the subsurface gravel and uniformly distributed by a perforated pipe along the trench bottom.

4. The upstream edge of a filter strip should be level and directly abut the contributing drainage area.

5. In areas where the soil infiltration rate has been compromised (e.g., by excessive compaction), the filter strip should be tilled prior to establishing vegetation. However, tilling will only have an effect on the top 12-18 inches of the soil layer. Therefore, other measures, such as planting trees and shrubs,

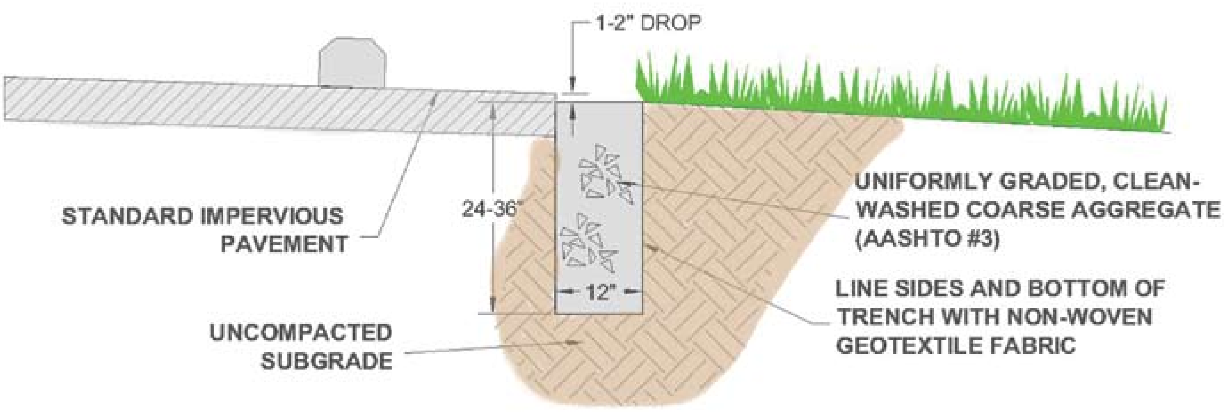

Figure 3 A Level Spreader device (gravel-filled trench)

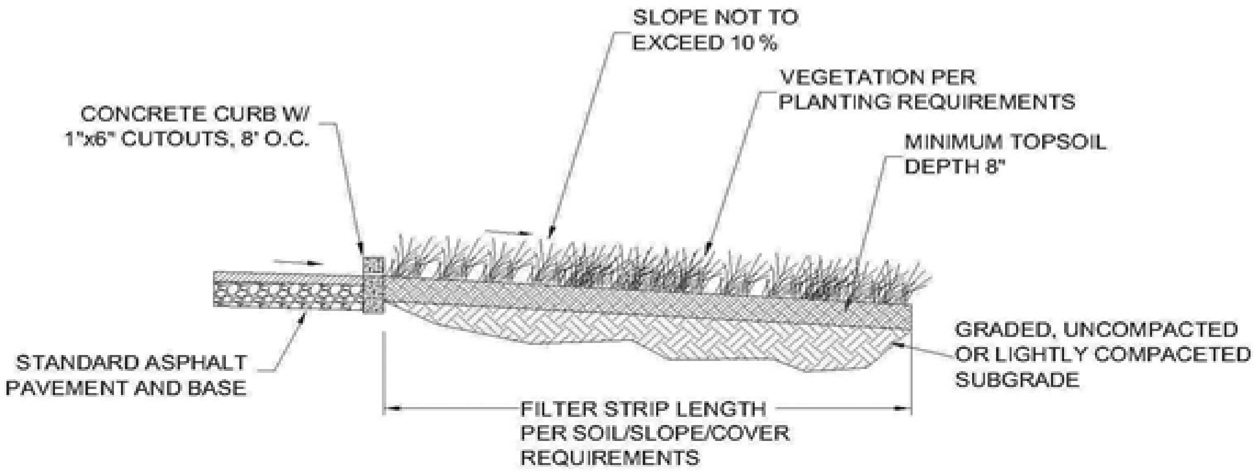

Figure 4 Concrete curb stop schematic

may be needed to provide deeper aeration. Deep root penetration will promote greater absorptive capacity of the soil.

6. The ratio of contributing drainage area to filter strip area should never exceed 6:1.

7. The filter strip area should be densely vegetated with a mix of salt-tolerant, drought-tolerant, and erosion-resistant plant species. Filter strip vegetation, whether planted or existing, may range from turf and native grasses to herbaceous and woody vegetation. The optimal vegetation strategy consists of plants with dense growth patterns, a fibrous root system for stability, good regrowth ability (following dormancy and cutting), and adaptability to local soil and climatic conditions. Native vegetation is always preferred. (See Recommended Plant List for BMPs Appendix for vegetation recommendations.)

8. Natural areas, such as forests and meadows, should never be unduly disturbed when creating a filter strip. If these areas are not already functional as natural filters, they may be enhanced by restorative methods or by constructing a level spreader.

9. The maximum lateral slope of a filter strip is one percent.

10. To prohibit runoff from laterally bypassing a strip, berms and/or curbs can be installed along the sides of the strip, parallel to the direction of flow.

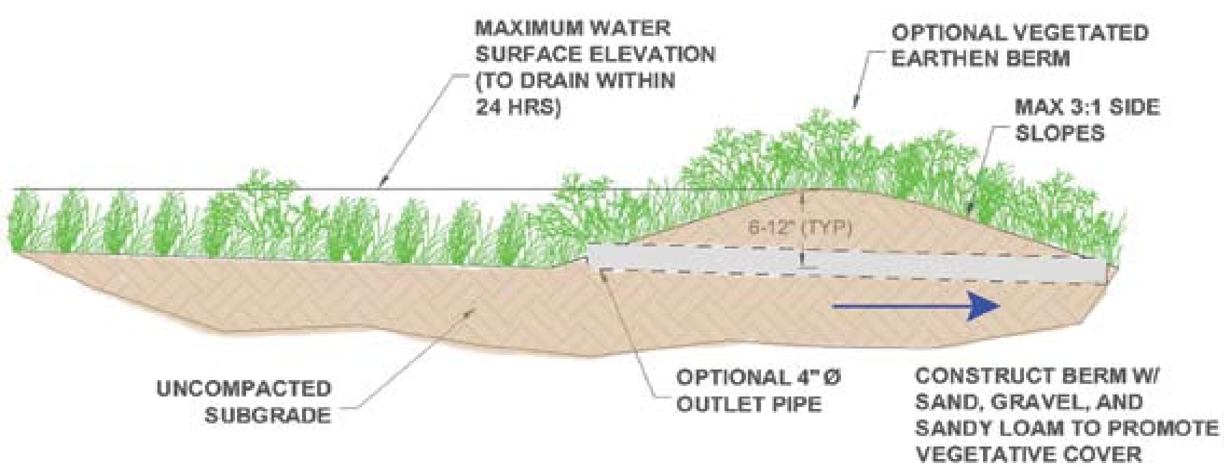

Figure 5 Optional earthen berm at bottom of vegetated filter strip

As shown in **Figure 6, Figure 7, Figure 8, Figure 9,** and **Figure 10**, the recommended filter strip length varies depending on the type of soil, the type of vegetation, and the filter strip slope. Generally, the more permeable the soil and/or the lower the slope, the shorter the filter strip may be for equivalent storm-water benefits.

County Regulated Drain Considerations: Special attention needs to be paid regarding the type and density of vegetation used if the natural drainage pathway or stream is or will be a part of the County Regulated Drain system. The County may require that at least one side of the regulated drain is clear of woody vegetation, with continuous access provided for reconstruction and maintenance. Pre-coordination with the County Surveyor's Office is highly recommended.

		Maximum Filter Strip Slope (Percent)	
Filter Strip Soil Type	**Hydrologic Soil Group**	**Turf Grass, Native Grasses and Meadows**	**Planted and Indigenous Woods**
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay Loam, Silty Clay, Clay	D	8	8

Table 1 Recommended Length as a Function of Slope, Soil Cover

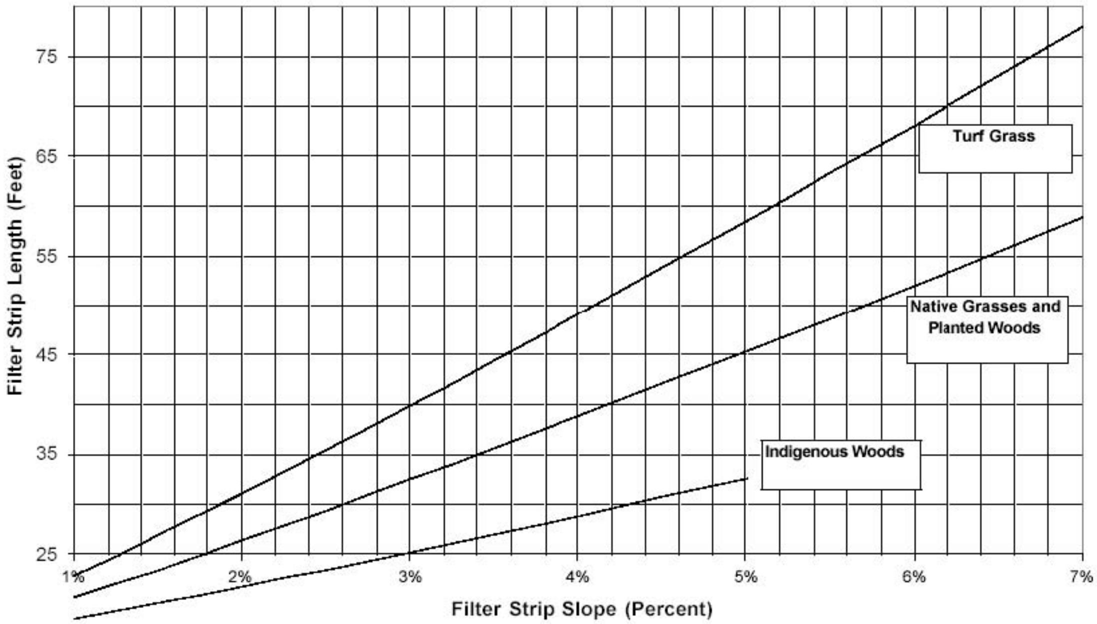

Figure 6 Sandy Soils with Hydrologic Soil Group A
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

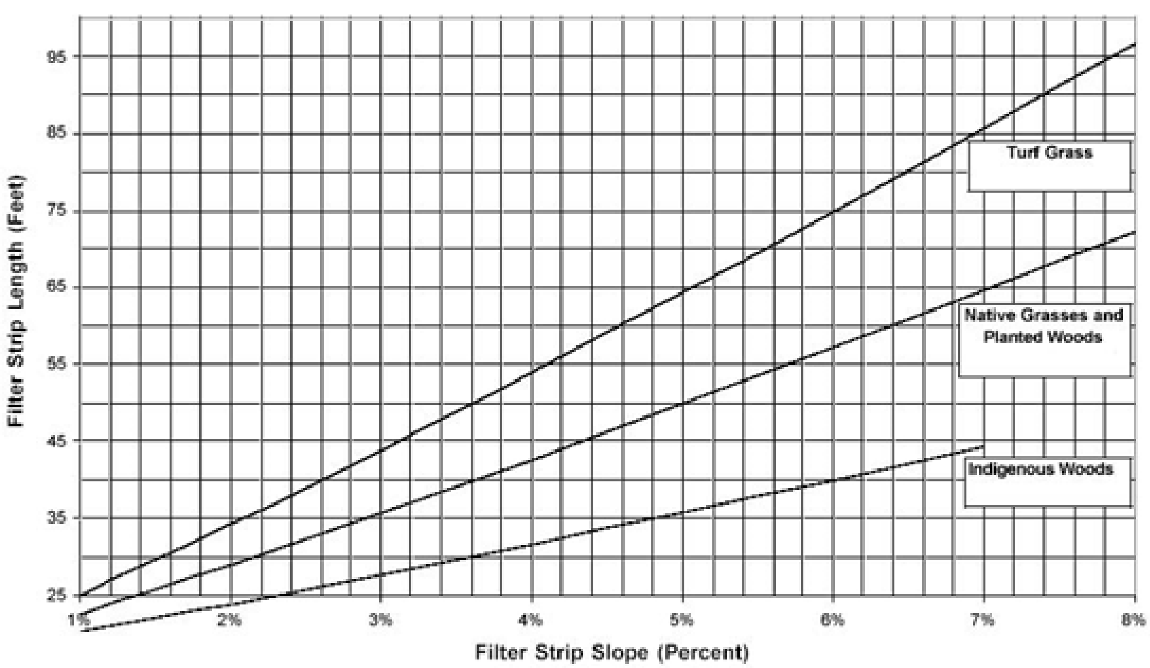

Figure 7 Sandy Loam Soils with Hydrologic Soil Group B
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

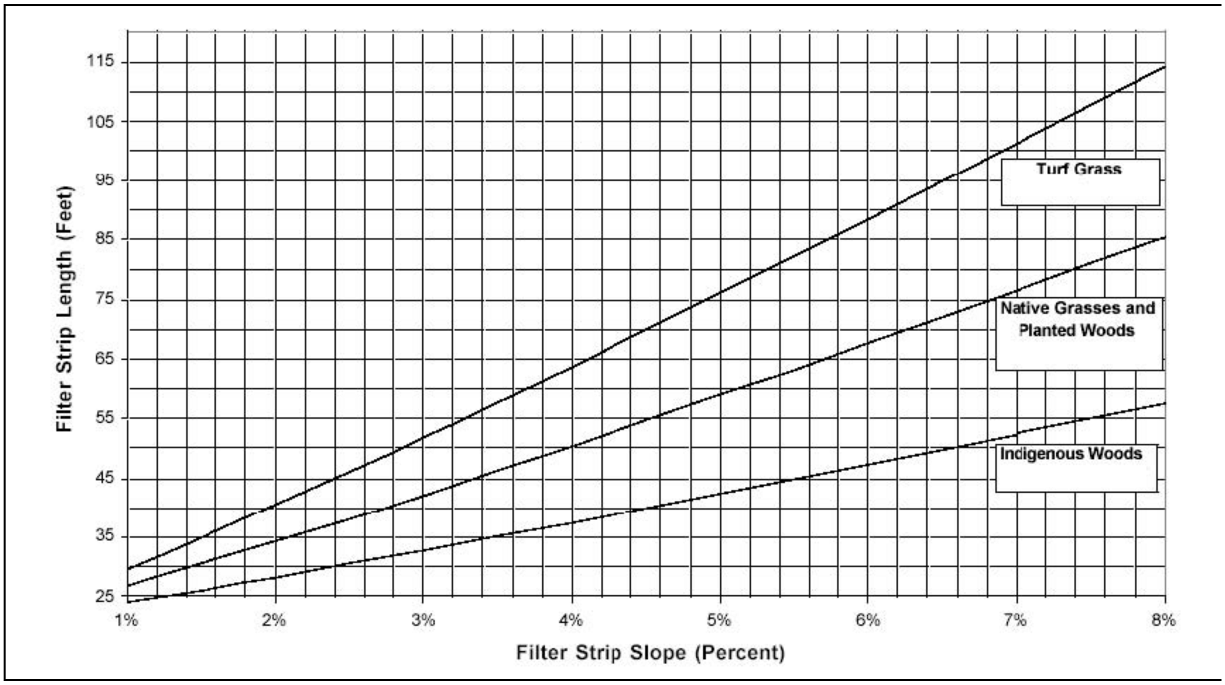

Figure 8 Loam, Silt-Loam Soils Hydrologic Soil Group B
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

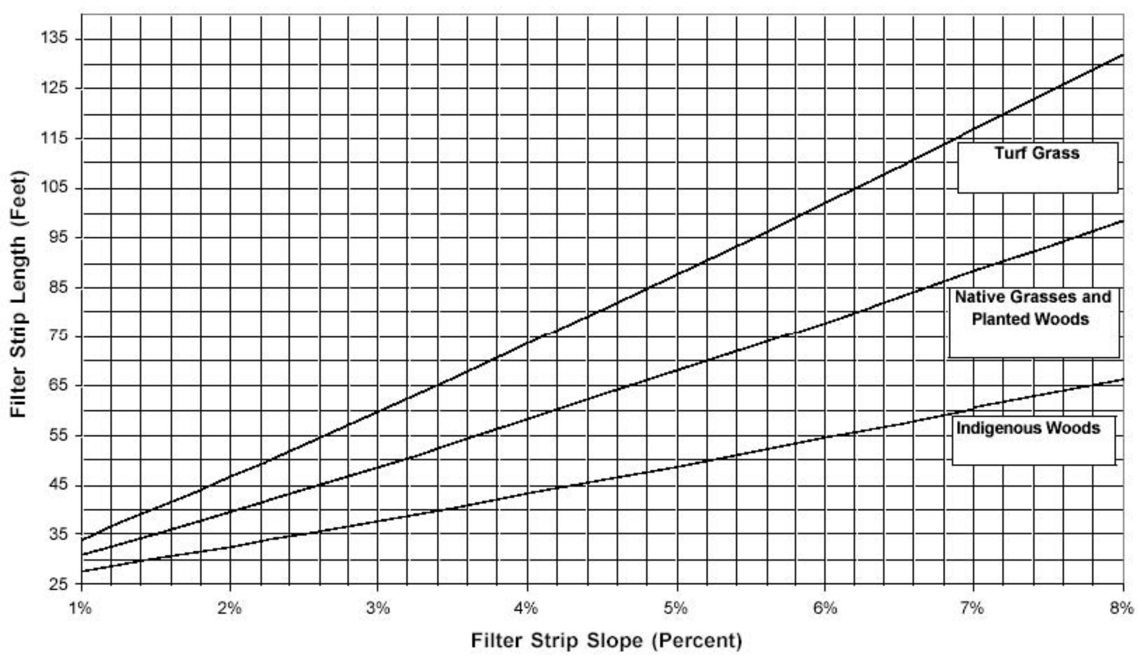

Figure 9 Sandy Clay Loam Soils with Hydrologic Soil Group C
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

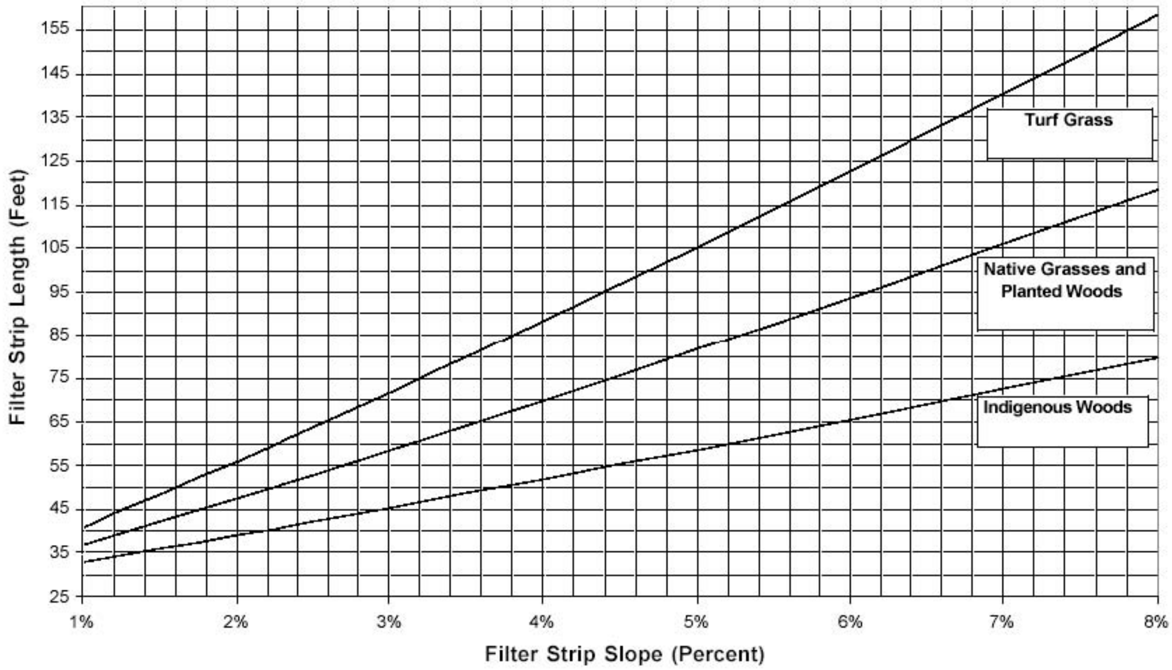

Figure 10 Clay Loam, Silty Clay or Clay Soils with Hydrologic Soil Group D
Source: New Jersey Stormwater Best Management Practices Manual, February 2004

Stormwater Functions and Calculations

Volume reduction

Although not typically considered a volume-reducing BMP, vegetated filter strips can achieve some volume reduction through infiltration and evapotranspiration, especially during small storms (storms less than approximately one inch). The volume reduction benefit of a filter strip can be estimated through hydrologic calculations. Two recommended methods are weighting the curve number of the drainage area with that of the filter strip (see LID discussion in Post-Construction Stormwater Quality Management Chapter of Technical Standards) or routing the runoff from the drainage area onto the filter strip area as inflow in addition to incident precipitation.

Large areas with dense vegetation may absorb unconcentrated flows that result from small storms, while areas covered by turf grass will absorb limited runoff. If a berm is constructed at the down-gradient end of the filter strip, an additional volume will be detained and may infiltrate the underlying soil.

Peak rate mitigation

Vegetated filter strips do not substantially reduce the peak rate of discharge. However, if a volume reduction is achieved through infiltration and evapotranspiration, a related reduction in peak rate will occur. If a berm is constructed at the down-gradient end of the filter strip, the rate of release of the detained volume may be controlled by an outlet structure.

Water quality improvement

Water quality benefits of vegetated filter strips are medium to high. The amount of benefit is based on flow characteristics and nutrient, sediment, and pollutant loadings of the runoff, as well as the length, slope, type, and density of vegetation in the filter strip.

Studies have shown 85 to 90 percent reductions in TSS and 40 to 65 percent reductions in nitrates (NO_2) from runoff being treated by vegetated filter strips. In these studies, the vegetated filter strips were between 25 and 29 feet wide with mild (0.7 percent to 1.7 percent) slopes, with grass and mixed vegetation.

Other studies have shown that suspended solids and metals are reduced to steady state amounts within several meters of the edge of the filter strip. (Note: If a filter strip is used for temporary sediment control, it should be regraded and reseeded immediately after construction and stabilization has occurred.)

Construction Guidelines

1. Follow the recommendations for materials in Recommended Materials Appendix.

2. Begin filter strip construction only when the up-gradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. The strip should be installed at a time of the year when successful establishment without irrigation is most likely. However, temporary irrigation may be needed in periods of little rain or drought.

3. For non-indigenous filter strips, clear and grade site as needed. Care should be taken to disturb as little existing vegetation as possible, whether in the designated filter strip area or in adjacent areas, and to avoid soil compaction. Grading a level slope may require removing existing vegetation.

4. Grade the filter strip area, including the berm at the toe of the slope. Pressure applied by construction equipment should be limited to four pounds per square inch to avoid excessive compaction or land disturbance.

5. Construct level spreader device at the upgradient edge of the filter strip. For gravel trenches, do not compact the subgrade. (Follow construction sequence for Infiltration Trench.)

6. Fine grade the filter strip area. Accurate grading is crucial for filter strips. Even the smallest irregularities may compromise sheet flow conditions.

7. Seed, sod, or plant more substantial vegetation, as proposed. If sod is proposed, place tiles tightly to avoid gaps, and stagger the ends to prevent channelization along the strip. Use a roller on sod to prevent air pockets from forming between the sod and soil.

8. Stabilize seeded filter strips with appropriate permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded filter strips should be required for at least the first 75 days following the first storm event of the season.

9. Once the filter strip is sufficiently stabilized after one full growing season, remove temporary erosion and sediment controls.

Maintenance

As with other vegetated BMPs, filter strips must be properly maintained to ensure their effectiveness. In particular, it is critical that sheet flow conditions are sustained throughout the life of the filter strip. Field observations of strips in urban settings show that their effectiveness can deteriorate due to lack of maintenance, inadequate design or location, and poor vegetative cover. Compared with other vegetated BMPs, filter strips require only minimal maintenance efforts, many of which may overlap with standard landscaping demands.

- Inspect sediment devices quarterly for clogging, excessive accumulations, and channelization for the first two years following installation, and then twice a year thereafter. Inspections should also be made after every storm event greater than one inch during the establishment period.

- Sediment and debris should be removed when buildup exceeds two inches in depth in either the filter strip or the level spreader. Improve the level spreader if erosion is observed. Rills and gullies observed along the strip may be filled with topsoil, stabilized with erosion control matting, and either seeded or sodded. For channels less than 12 inches wide, filling with crushed gravel, which allows grass to creep in over time, is acceptable. For wider channels (greater than 12 inches), regrading and reseeding may be necessary. Small bare areas may only require overseeding. Regrading may also be required when pools of standing water are observed along the slope. In no case should standing water be tolerated for longer than 48 to 72 hours.

- If check dams are proposed, inspect for cracks, rot, structural damage, obstructions, or any other factors that cause altered flow patterns or channelization. Inlets or sediment sumps that drain to filter strips should be cleaned periodically or as needed.

- Remove sediment when the filter strip is thoroughly dry. Dispose of sediment and debris at a suitable disposal or recycling site that complies with applicable local, state, and federal waste regulations.

- When a filter strip is used for sediment control, it should be regraded and reseeded immediately after construction.

- Guidance information, usually in written manual form, for operating and maintaining filter strips, should be provided to all facility owners and tenants. Facility owners are encouraged to keep an inspection log, for recording all inspection dates, observations, and maintenance activities.

- Grass cover should be mowed to maintain a height of 4-6 inches.

- Invasive plants should be removed on an annual basis. Vegetative cover should be sustained at 85 percent and reestablished if damage greater than 50 percent is observed.

- If a filter strip exhibits signs of poor drainage, periodic soil aeration or liming may help to improve infiltration.

Winter Considerations

Filter strips often make convenient areas for snow storage. Thus, vegetation should be salt-tolerant and the maintenance schedule should include removing sand buildup at the toe of the slope.

The bottom of the gravel trench (if used as the level spreader) should be placed below the frost line to prohibit water from freezing in the trench. The perforated pipe in the trench should be at least eight inches in diameter to further discourage freezing.
Other water quality options may be explored to provide backup to filter strips during the winter, when pollutant removal ability is reduced.

Cost

The cost of constructing filter strips includes grading, sodding (when applicable), installing vegetation, constructing a level spreader, and constructing a pervious berm, if proposed. Depending on whether seed or sod is applied, enhanced vegetation use or design variations such as check dams, construction costs may range anywhere from no cost (assuming the area was to be grassed regardless of use as treatment) to $50,000 per acre. The annual cost of maintaining filter strips (mowing, weeding, inspecting, litter removal, etc.) generally runs from $100 to $1,400 per acre and may overlap with standard landscape maintenance costs. Maintenance costs are highly variable, as they are a function of frequency and local labor rates.

Designer/Reviewer Checklist for Vegetated Filter Strips

Soil type and HSG category: ____

ITEM	Page No.	YES	NO	N/A	NOTES
Sheet flow provided?	1				
Recommended slope ranges followed? ➢ *Max. lateral slope = **1%***	1				
Appropriate length for soil, vegetation, and slope?	4-7				
Slope of drainage area below five percent?	--				
If not, is energy dissipation provided?	3				
Length/area of incoming drainage appropriately limited?	3				
Receiving vegetation considered?	2				
Located in undisturbed virgin soil?	4				
If not, will soil be properly compacted and stabilized?	8,9				
Appropriate vegetation selected for stabilization?	3,4				
Feasible construction process and sequence?	8,9				
Soil compaction avoided or mitigated?	--				
Erosion and sedimentation control provided to protect filter strip during construction?	8,9				
Maintenance accounted for and plan provided? ➢ *Remove sediment/debris if > 2 inches deep.* ➢ *Standing water should not exceed 48-72 hours* ➢ *Grass cover: 4-6 inches high*	9				
Additional Design Considerations ➢ *Underlying soils should have low permeability, ranging between 0.06 and 0.6 inches/hour* ➢ *Hydraulic residence time no less than 5 minutes; optimal time is 9 minutes* ➢ *Average velocity no greater than 0.9 feet/second* ➢ *Average depth of flow no more than 0.5 inches*	--				

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

VEGETATED ROOF

Vegetated roofs, or green roofs, are conventional rooftops that include a thin covering of vegetation allowing the roof to function more like a vegetated surface. The overall thickness of the vegetated roof may range from 2 to 6 inches, typically containing multiple layers consisting of waterproofing, synthetic insulation, non-soil engineered growth media, fabrics, synthetic components, and foliage.

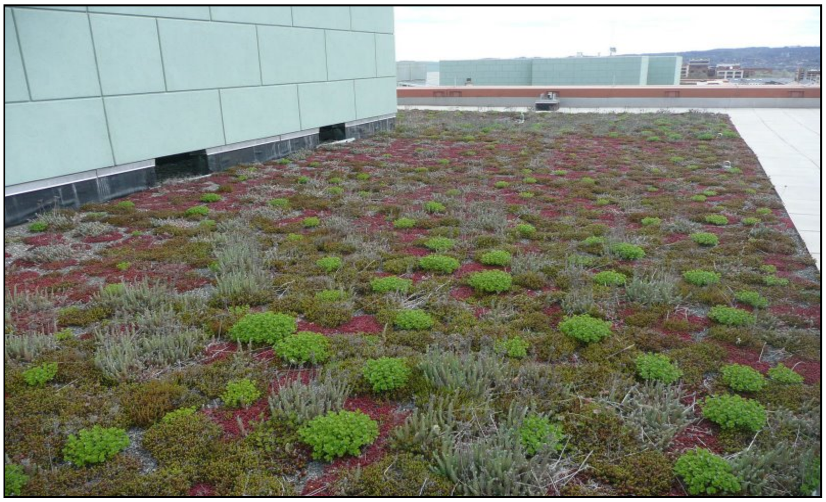

Figure 1 Vegetated Roof, Washington, DC (USEPA, picasaweb)

Applications		Stormwater Quantity Functions	
Residential	Limited	Volume	Med/High
Commercial	Yes	Groundwater Recharge	Low*
Ultra Urban	Yes	Peak Rate	Medium
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Medium
Highway/Road	N/A	TP	Medium
Recreational	Yes	TN	Medium
		Temperature	High

Additional Considerations	
Cost	High
Maintenance	Medium
Winter Performance	Medium

Variations

- Intensive
- Semi-intensive
- Extensive

Key Design Features

- Extensive roofs are most commonly used for rainfall runoff migration
- Roofs with pitches steeper than 2:12 (9.5 degrees) must incorporate supplemental measures

Benefits

- Good stormwater volume control
- Heating and cooling energy benefits
- Increased lifespan of roof
- Heat island reduction
- Enhance habitat value

Limitations

- Cost (intensive systems)
- Careful design and construction required
- Maintenance requirements until plants established
- Can't store or treat stormwater from other parts of the property

* Although vegetated roofs can be used very successfully in combination with infiltration systems.

Description and Function

Vegetated roofs involve growing plants on rooftops, thus replacing the vegetated footprint that was removed when the building was constructed. Vegetated roof covers are an "at source" measure for reducing the rate and volume of runoff released during rainfall events. The water retention and detention properties of vegetated roof covers can be enhanced through selection of the engineered media and plants. Depending on the plant material and planned usage for the roof area, modern vegetated roofs can be categorized as systems that are intensive, semi-intensive, or extensive (**Table 1**).

Intensive vegetated roofs utilize a wide variety of plant species that may include trees and shrubs, require deeper substrate layers (usually greater than four inches), are generally limited to flat roofs, require 'intense' maintenance, and are often park-like areas accessible to the general public.

Extensive vegetated roofs are limited to herbs, grasses, mosses, and drought tolerant succulents such as sedum, can be sustained in a shallow substrate layer (less than four inches), require minimal maintenance once established, and are generally not designed for access by the public. These vegetated roofs are typically intended to achieve a specific environmental benefit, such as rainfall runoff mitigation. Extensive roofs are well suited to rooftops with little load bearing capacity and sites which are not meant to be used as roof gardens. The mineral substrate layer, containing little nutrients, is not very deep but suitable for less demanding and low-growing plant communities.

Semi-intensive vegetated roofs fall between intensive and extensive vegetated roof systems. More maintenance, higher costs and more weight are the characteristics for this intermediate system compared to that of the extensive vegetated roof.

Vegetated system layers

A proprietary system provides a growing environment on the roof which adequately compensates for the plant's natural environment. It ensures reliable technical and ecological functionality for decades. Vegetated roof systems contain the following functional layers (from bottom to top):

Root barrier: The root barrier protects the roof construction from being damaged by roots. If the waterproofing is not root resistant a separate root barrier has to be installed.

Waterproof membrane: This layer protects the roof structure from moisture and can include a unique root-resistant compound to prevent roots from penetrating.

Protection layer: A specially designed perforation resistant protection mat prevents mechanical damage of the root barrier and roof construction during the installation phase. Depending on the thickness and the material the protection layer can also retain water and nutrients.

Drainage Layer: The drainage layer allows for excess water to run-off into the water outlets. Depending on the design and the material the drainage layer has additional functions such as water storage, enlargement of the root zone, space for aeration of the system and protection for the layers below it. Due to the weight constraints of the roof, the drainage layer is made of light-weight materials. Molded drainage elements made of rubber or plastic are used quite often. Other drainage layers are made of gravel, lava, expanded clay or clay tiles.

Filter layer: The filter layer separates the plant and substrate layers from the drainage layer below. Especially small particles, humic and organic materials, are retained by the filter sheet and are therefore available for the plants. In addition, the filter sheet ensures that the drainage layer and the water outlet are not clogged with silt. Filter layers are preferably made of geo-textiles such as fleece or other woven materials.

Growing medium: The growing medium is the basis of the vegetated roof. A sufficient depth for the root zone has to be ensured as well as an adequate nutrient supply and a well balanced water-air relation. Depending on the type of vegetated roof and the construction requirements, a variety of different system substrates are available.

	Extensive Vegetated Roof	Semi-Intensive Vegetated Roof	Intensive Vegetated Roof
Maintenance	Low	Periodically	High
Irrigation (after plants are established)*	No	Periodically	Regularly
Plant Communities	Moss, Sedum, Herbs, and Grasses	Grass, Herbs, and Shrubs	Perennials, Shrubs, and Trees
System build-up height	60-200 mm	120-250 mm	150-400 mm Underground garages = > 1000 mm
Weight	60 - 150 kg/m^2 13-30 lbs/ ft^2	120 - 200 kg/m^2 25-40 lbs/ ft^2	180 - 500 kg/m^2 35-100 lbs/ft^2
Construction costs	Low	Medium	High
Desired use	Ecological protection layer	Designed vegetated roof	Park-like garden

Table 1 Vegetated roof types
**Irrigation is required regularly to establish plant communities, especially during the first season.*
Source: Adapted from International Green Roof Association

Light-weight mineral materials, with high water retention capacity and good water permeability, such as lava, pumice, expanded clay, expanded schist, and clay tiles, have proven to be reliable for many years. Untreated organic material and top soil have disadvantages in terms of weight and drainage function; they are only used as additions to mineral substrates.

Plant level: The plant selection depends on the growing medium as well as local conditions, available maintenance and the desired appearance. Low maintenance, durable and drought resistant plants are used for extensive vegetated roofs, versus, a nearly limitless plant selection for intensive vegetated roofs.

Variations

Some specialized vegetated roof companies offer installation using vegetated blankets/mats or trays. Pre-vegetated blankets/mats are grown off-site and brought to the site for installation (similar to the concept of sod for grass). They can provide an immediate vegetative coverage which can prevent erosion, reduce installation times, and reduce maintenance during what would otherwise be the establishment period for vegetation.

Modular systems are manufactured trays filled with various vegetated roof layers (often pre-vegetated as well) that are delivered to the site and installed on a prepared roof. Manufacturers of these systems claim that benefits include faster installation and easier access to the roof if maintenance or leak repairs are necessary (in addition to the potential benefits of a pre-vegetated system). Others argue that these benefits are not significant and that trays can have drawbacks such as increased cost, poor aesthetics (module edges being visible), and reduced performance (wet and dry spots resulting from the barriers between modules in the system).

Extensive vegetated roofs

Extensive vegetated roofs are the most commonly used systems due to their higher mitigation of stormwater runoff as well as their lower cost compared to the other systems. Extensive systems have three variations of assemblies that can be considered in design.

Single media assemblies

Single media assemblies (**Figure 2**) are commonly used for pitched roof applications and for thin and lightweight installations. These systems typically incorporate very drought tolerant plants and utilize coarse engineered media with high permeability. A typical profile would include the following layers:

1. Waterproofing membrane
2. Protection layer
3. Root barrier (optional, depending on the root-fastness of the waterproofing)
4. Drainage layer
5. Filter layer
6. Growth media
7. Vegetation

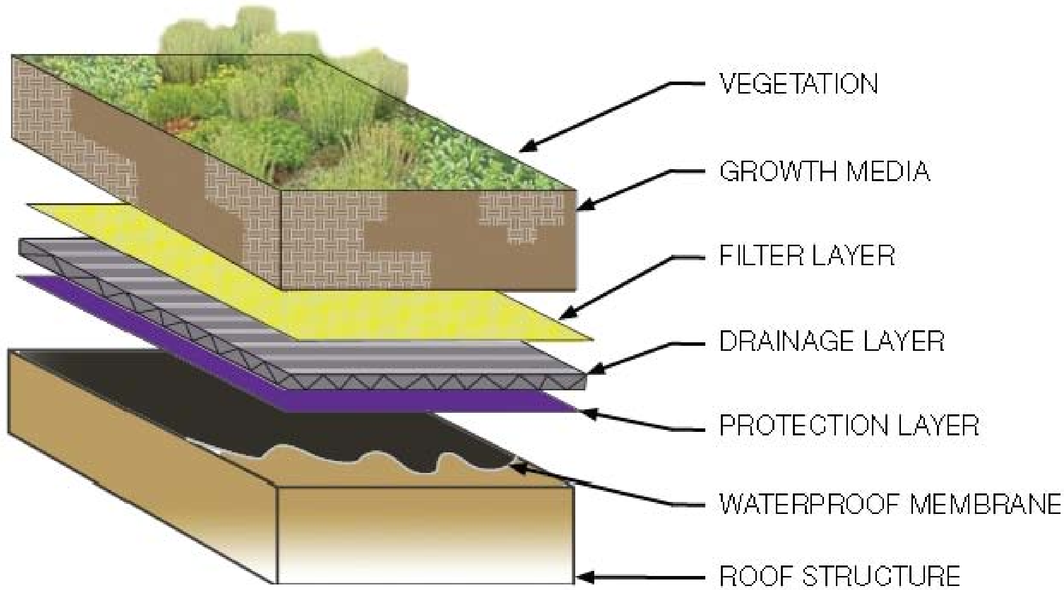

Figure 2 Single media assembly

Pitched roof applications may require the addition of slope bars, rigid slope stabilization panels, cribbing, reinforcing mesh, or similar method of preventing sliding instability.

Flat roof applications with mats as foundations typically require a network of perforated internal drainage conduit to enhance drainage of percolated rainfall to the deck drains or scuppers.

Dual media assemblies

Dual media (**Figure 3**) assemblies utilize two types of non-soil growth media. In this case a finer-grained media with some organic content is placed over a base layer of coarse lightweight mineral aggregate. They do not include a geocomposite drain.

The objective is to improve drought resistance by replicating a natural alpine growing environment in which sandy topsoil overlies gravelly subsoil. These assemblies are typically 4 to 6 inches thick and include the following layers:

1. Waterproofing membrane
2. Root barrier/ protection layer
3. Coarse-grained drainage media
4. Filter layer
5. Growth media
6. Vegetation

These assemblies are suitable for roofs with pitches less than, or equal to about 1.5:12 (7.1 degrees). Large vegetated covers will generally incorporate a network of perforated internal drainage conduit located within the coarse grained drainage layer.

Dual media with synthetic retention/detention layer

These assemblies introduce impervious plastic panels with cup-like receptacles on their upper surface (i.e., a modified geocomposite drain sheet). The panels are in-filled with coarse lightweight mineral aggregate. The cups trap and retain water. They also introduce an air layer at the bottom of the assembly. A typical profile would include:

1. Waterproof membrane
2. Protection layer
3. Retention/detention panel
4. Coarse-grained drainage media
5. Filter layer
6. Growth media
7. Vegetation

These assemblies are suitable on roof with pitches less than or equal to 1:12 (4.8 degrees). Due to their complexity, these systems are usually a minimum of five inches deep. If required, irrigation can be provided via surface spray or mid-level drip.

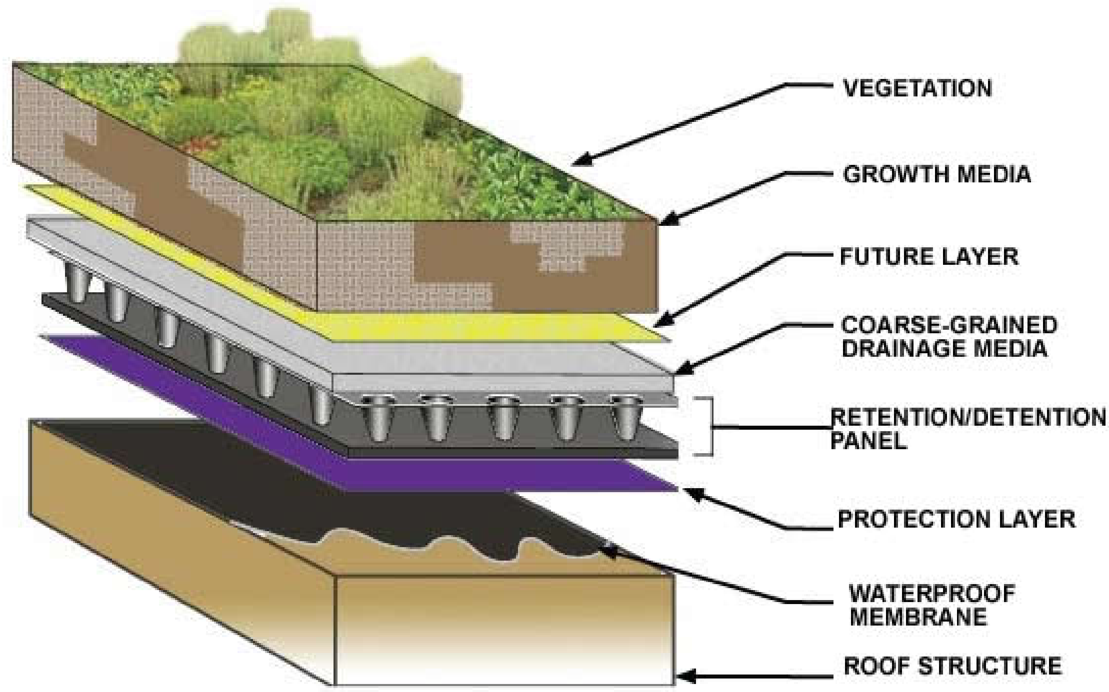

Figure 3 Dual media assembly

Treatment Train

Vegetated roof covers are frequently combined with ground infiltration measures. This combination can be extremely effective for stormwater management and is one of the best ways to replicate the natural hydrologic cycle. Vegetated roofs evapotranspirate a significant fraction of annual rainfall and typically discharge larger storm events relatively slowly. If overflow is directed to an infiltration system, the discharge can be infiltrated efficiently as the system has more time to absorb water as it is slowly released from the roof. Vegetated roof covers improve the efficiency of infiltration devices by:

- Reducing the peak runoff rate,
- Prolonging the runoff, and
- Filtering runoff to produce a cleaner effluent.

Benefits

Establishing plant material on rooftops provides numerous ecological and economic benefits including stormwater management, energy conservation, mitigation of the urban heat island effect, increased longevity of roofing membranes, as well as providing a more aesthetically pleasing environment to work and live. A major benefit of green roofs is their ability to absorb stormwater and release it slowly over a period of several hours, retaining 60-100 percent of the stormwater they receive, depending on the duration and the intensity of the storm.

In addition, green roofs have a longer life-span than standard roofs because they are protected from ultraviolet radiation and the extreme fluctuations in temperature that cause roof membranes to deteriorate. A vegetated roof has a life expectancy of 60 years — three times as long as a traditional roof.

As pervious surfaces are replaced with impervious surfaces due to urban development, the need to recover green space is becoming increasingly critical for the health of our environment. Vegetated roof covers have been used to create functional meadows and wetlands to mitigate the development of open space. This can be accomplished with assemblies as thin as six inches.

Design Considerations

Roof substructure

Wooden constructions, metal sheeting as well as reinforced concrete decks can be considered as appropriate roof substructures. The base for the vegetated roof is a waterproof roof construction with appropriate load bearing capacity.

Root barrier

Root barriers should be thermoplastic membranes with a thickness of at least 30 mils. Thermoplastic sheets can be bonded using hot-air fusion methods, rendering the seams safe from root penetration. Membranes that have been certified for use as root-barriers are recommended.

Over a period of time roots can damage the water-proofing and roof construction if there have been no corresponding protection measures taken. The root resistance of the waterproofing is determined from the "Procedure for investigating resistance to root penetration at green-roof sites" by the FLL (The Landscaping and Landscape Development Research Society). Over 70 different waterproofing products meet the requirements of this test. If the waterproofing is not root resistant, an additional root barrier has to be installed. Aside from the roof surface, the upstands, perimeters, joints and roof edges also have to be protected against root penetration.

Growth media

Growth media should be a soil-like mixture containing not more than 15 percent organic content. The appropriate grain-size distribution is essential for achieving the proper moisture content, permeability, nutrient management, and non-capillary porosity, and 'soil' structure. The grain-size guidelines vary for single and dual media vegetated cover assemblies.

Separation fabric

Separation fabric should be readily penetrated by roots, but provide a durable separation between the drainage and growth media layers. (Only lightweight nonwoven geotextiles are recommended for this function.)

Roof penetrations

For vegetated roofs, the following upstand and perimeter heights have to be considered:

- Upstand height for adjacent building parts and penetrations: minimum of 6 inches.
- Upstand height for roof edges: minimum of 4 inches.

Important: The upstand height is always measured from the upper surface of the vegetated roof system build up or gravel strip. Clamping profiles guarantee reliable protection and a tight connection of the upstand areas. Roof penetrations (e.g. water connections, building parts for the usage of the roof area, etc.), when possible, should be grouped in order to keep roof penetration to a minimum.

> Even though it is possible to build pitched green roofs with a slope of 45º, it is not recommended to exceed 10 º due to significant limited accessibility for upkeep and maintenance.

Roof slope

Using modern technologies it is possible to install a reliable vegetated roof system not only on conventional flat roofs, but also on saddle roofs, shed roofs and barrel roofs. Special technical precautions for the mitigation of existing shear forces and erosion are only necessary for a roof slope over 10°.

Roofs with a slope of more than 45° are normally not suitable for a vegetated roof system. Roofs with a slope of less than two percent are special roof constructions on which puddles often develop.

In order to avoid damage to extensive vegetated roofs by water retention, specific arrangements for the roof drainage are necessary. In contrast, it can be beneficial for intensive vegetated roofs to design the roof construction without slope to allow for dam up irrigation.

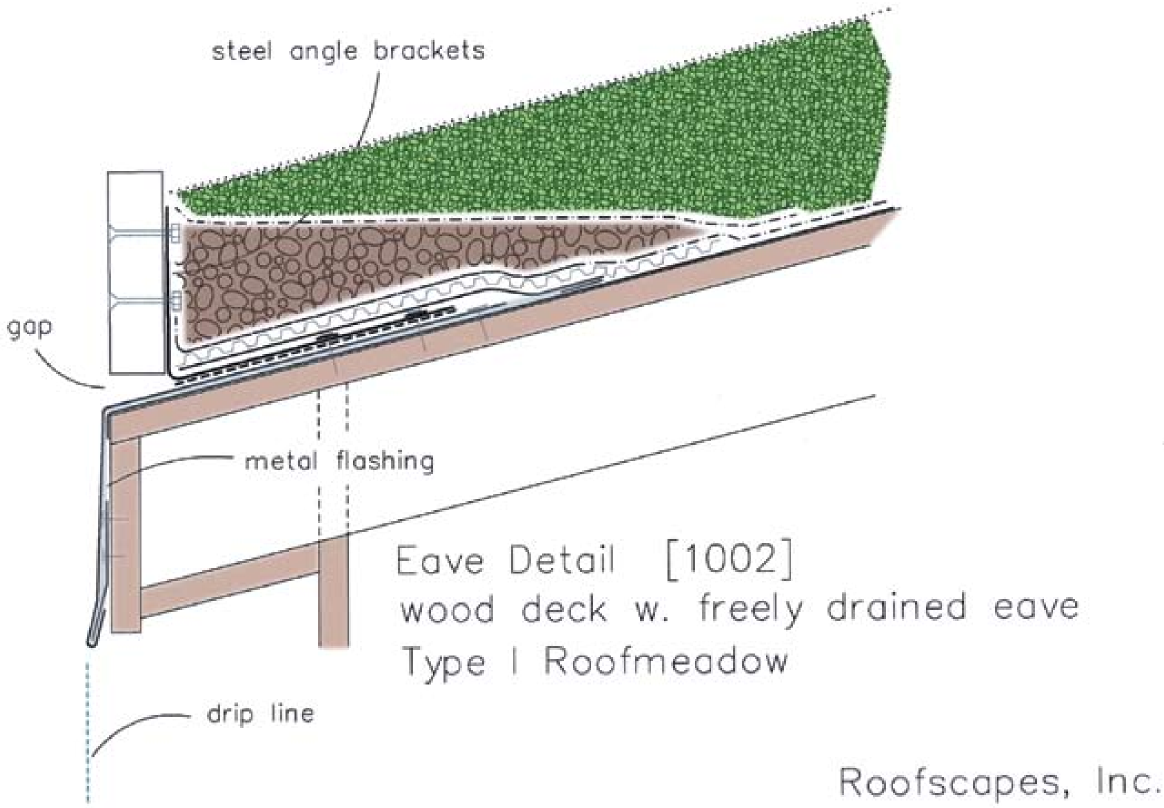

Figure 4 Example Eave Detail for sloped roof
Source: Roofscapes, Inc.

Load calculations

The maximum load bearing capacity of the roof construction must be considered when installing vegetated roofs. Therefore, the water saturated weight of the green roof system, including vegetation must be calculated as permanent load. Extensive vegetated roofs weigh between 60-150 kg/m^2 (13.0-30.0 lb/ft^2.) depending on the thickness of the vegetated roof system build-up. Trees, shrubs, and construction elements such as pergolas and walkways cause high point loads and, therefore, have to be calculated accordingly.

Wind uplift

A vegetated roof must be tight to the roof, especially in cases of strong wind. When designing and installing the vegetated roof, safety measures against wind uplift are to be considered.

This is especially important when the vegetated roof provides the load for a loose laid waterproofing and root barrier. The actual influence from the wind depends on the local wind zone, height of the building, roof type, slope, and area (whether corner, middle or edge) and the substructure.

Roof drainage

Vegetated roof systems store a major part of the annual precipitation and release it to the atmosphere by transpiration. Depending on the thickness of the vegetated roof system build-up and rain intensity, surplus water may accumulate at certain times and must be drained off the roof area. The number of roof outlets and the penetrability factor, or more precisely, the water retaining capacity of the vegetated roof system build-up, has to be adjusted to the average local precipitation.

Roof outlets are to be kept free of substrate and vegetation and have to be controllable at all times. For this purpose “inspection chambers” are installed over the roof outlets. Due to safety precautions, roof areas with inlayed drainage must always have two drainage outlets or one outlet and one safety overflow. For facades and roof areas, gravel strips,

Pitched Vegetated Roofs

Technical Requirements

Root resistant waterproofing is necessary for pitched vegetated roofs; installing an additional root barrier, requires much effort and increases the risk of slippage. Stable abutments have to be installed on the eaves edges to transfer shear forces from the vegetated roof system build-up and the additional snow load into the roof construction. Additional shear barriers may be necessary to transfer the shear forces depending on the roof slope and the roof length. It is recommended the design for the shear barriers and the eaves profiles be done by a structural engineer. With increasing slope, the vegetated roof system build-up is more complicated and the substrate has to be protected from erosion; plastic grid elements can be used for this purpose.

Plant Selection

The success of the landscaping on pitched roofs depends on the plants. Fast surface coverage is the highest priority. A dense planting of root ball plants or pre-cultivated vegetation mats are used in cases of steep slopes and allow for rapid coverage. It is also important to consider the exposure of the roof area, the slope and the location of the building when selecting plants. Perennials and grasses can be used whereas Sedum is the most suitable for pitched roofs, due to the species' high water retention capacity and erosion protection. The water run-off is much faster on pitched roofs compared to a flat roof. It is advisable to plan for an additional irrigation system to provide water during dry periods. The irrigation can be provided either by drip irrigation or by sprinkler systems.

gullies and grids provide fast drainage of rainwater into the drainage system.

Irrigation

Extensive vegetated roofs with drought resistant plant species have to be irrigated only during planting and installation maintenance over the first two years. After its establishment, the annual rainfall is sufficient to sustain the vegetation. In contrast, the requirements are more involved for intensive vegetated roofs with lawn, shrubs, or trees. An adequate number of precisely dimensioned hoses with automatic irrigation units make plant maintenance during drought periods more manageable. The water supply for roof gardens with no slope can be increased through additional dam-up irrigation. Vegetated roofs can also be irrigated with cistern water.

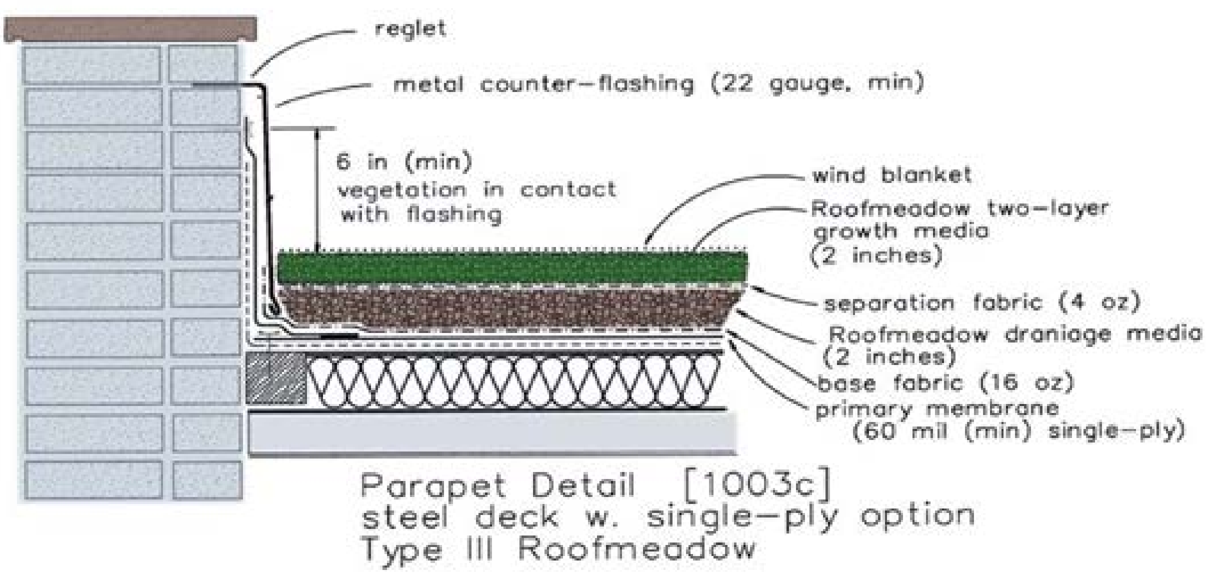

Figure 5 Example parapet flashing detail for flat roof
Source: Roofscapes, Inc.

Fire prevention

As a part of the "hard roof" classification, intensive vegetated roofs provide preventative fire protection in the case of sparks and radiating heat. The criteria that extensive vegetated roofs must meet in order to be considered fire resistant, are already met by most vegetated roof systems that are offered by suppliers. Openings within the vegetated roof (e.g. skylights) need to be installed with a vegetation free zone (approximately 20 inches). On larger roof areas a vegetation free zone (e.g. gravel strip or concrete slabs) are to be installed at least every 130 feet.

Vegetation Considerations

Extensive vegetated roofs

Plants for extensive vegetated roofs have to survive intense solar radiation, wind exposure, drought, low nutrient supply, freezing temperatures and limited root area. Suitable plant varieties are those growing in severe locations with little moisture and nutrient supply, such as dry meadows. The main varieties are sedum, and delosperma. The plants are able to store high amounts of water in the leaves, are stress resistant and recover easily from periods of drought. Other varieties such as dianthus species, asteraceae and ornamental grasses are also suitable for these conditions.

Intensive green roofs

Having an appropriate vegetated roof system and sufficient growing medium (with higher root penetration volume, nutrients and water supply) growth of sophisticated plant varieties on the roof is possible. The selected plants need to be resistant to intense solar radiation and strong winds. Vegetation with various plant varieties such as perennials, herbs, grasses and trees allow for a natural character on the roof. Having a broader plant community increases the amount of maintenance required.

Stormwater Functions and Calculations

The performance of vegetated roof covers as stormwater best management practices cannot be represented by simple algebraic expressions used for surface runoff. In the analysis of vegetated roof covers, the water that is discharged from the roof is not surface runoff, but rather underflow, i.e., percolated water. The rate and quantity of water released during a particular storm can be predicted based on knowledge of key physical properties, including:

- Maximum media water retention
- Field capacity
- Plant cover type
- Saturated hydraulic conductivity
- Non-capillary porosity

The maximum media water retention is the maximum quantity of water that can be held against gravity under drained conditions. Standards that have been developed specifically for measuring this quantity in roof media are available from FLL and ASTM (E2399).

Conventional runoff coefficients, such as the NRCS runoff curve number, CN, can be back-calculated from computer simulation or measurements of vegetated roof cover assemblies. However, these coefficients will only apply for the specific design storm for which they have been determined. Runoff reduction recognition in CN determination for this practice is discussed under LID Approach in Post-Construction Stormwater Management Chapter of Technical Standards.

Volume reduction

All vegetated roof covers have both retention and detention volume components. Benchmarks for these volumes can be developed from the physical properties described above.

Peak rate mitigation

Vegetated roof covers can exert a large influence on peak rate, especially in less extreme storms such as the 1-, 2-, and 5-year storms. Because volume is reduced, there is some peak rate reduction achieved for all storms. An evaluation of peak runoff rates requires either computer simulation or measurements made using prototype assemblies.

A general rule for vegetated roof covers is that rate of runoff from the covered roof surface will be less than or equal to that of open space (i.e., NRCS curve number of about 65) for storm events with total rainfall volumes up to three times the maximum media water retention of the assembly. For example, a representative vegetated roof cover with maximum moisture retention of one inch will react like open space for storms up to and including the three-inch magnitude storm.

Using computer simulations, municipalities could generate a table of CN values for specific design storms and green roof types. The table would relate maximum moisture capacity to the CN coefficients. Runoff reduction recognition in CN determination for this practice is discussed under LID Approach in Post-Construction Stormwater Management Chapter of Technical Standards.

Water quality improvement

Direct runoff from roofs is a contributor to pollutants in stormwater runoff. Vegetated roof covers can significantly reduce this source of pollution. Assemblies intended to produce water quality benefits will employ engineered media with almost 100 percent mineral content. Furthermore, following the plant establishment period (usually about 18 months), on-going fertilization of the cover is no longer needed. Experience indicates that it may take five or more years for a water quality vegetated cover to attain its maximum pollutant removal efficiency.

Maintenance

- Irrigation will be required as necessary during the plant establishment period and in times of drought.

- During the plant establishment period, three to four visits to conduct basic weeding, fertilization, and infill planting is recommended.

- The soluble nitrogen content (nitrate plus ammonium ion) of the soil should be adjusted to between one and five parts per million, based on soil test.

- Once plants are established, it is crucial to maintain the roof once or twice a year. Weeds and other unwanted plants on the entire roof, at the perimeters and at the upstands need to be removed. For grass and herb vegetation the organic buildup has to be removed once a year. Intensive vegetated roofs require higher maintenance and service throughout the year.

Dam-up Irrigation in Vegetated Roof

Intensive Vegetated Roofs depend mainly on additional irrigation. To install an irrigation system which does not use fresh water, a water dam-up irrigation unit is recommended.

Requirements of a dam-up irrigation unit:

- flat roof
- dam-up elements above roof outlets
- an appropriate drainage layer with the necessary height

In case of heavy rain the reservoir is filled primarily and any excess water is collected in the cistern. During dry periods the water on the roof is used first, then water is pumped from the cistern onto the roof and supplied to the plants.

This process can be carried out either manually or electronically. The water in the cistern can also be used for other purposes, provided the reservoir is big enough.

Winter Considerations

Applicable snow load must be considered in the design of the roof structure.

Cost

The construction cost of vegetated roof covers varies greatly, depending on factors such as:

- Height of the building
- Accessibility to the structure by large equipment such as cranes and trailers
- Depth and complexity of the assembly
- Remoteness of the project from sources of material supply
- Size of the project

However, under 2007 market conditions, extensive vegetated covers for roof will typically range between $8 and $16 per square foot, including design, installation, and warranty service (not including waterproofing). Basic maintenance for extensive vegetated covers typically requires about 2-3 person-hours per 1,000 square feet, annually.

Although vegetated roofs are relatively expensive compared to other BMPs in terms of stormwater management, they can have other significant benefits which serve to reduce their life-cycle costs. For example, the longevity of the roof system may be greatly increased. In addition, heating and cooling costs can be significantly reduced.

Designer/Reviewer Checklist for Vegetated Roofs

Type of vegetated roof(s) proposed: ____

ITEM	Page No.	YES	NO	N/A	NOTES
Load and structural capacity analyzed?	7				
Waterproofing layer and protection adequate?	2,6				
Leak protection system provided?	3-5				
Internal drainage capacity for large storms?	--				
Appropriate growing medium?	3,6				
Appropriate drainage media and/or layer?	2				
Geotextile/filter fabric specified?	2,6				
Good detailing (flashings, penetrations, drains, gravel edges, etc.)?	--				
Slope stability provided, if necessary?	4,8				
Appropriate vegetation selected?	3,6, 8,9				
Plant establishment (temporary irrigation/fertilization) procedures provided?	8				
Erosion control / wind protection provided?	7				
Maintenance accounted for and plan provided?	10				

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BMP Fact Sheet

VEGETATED SWALE

A vegetated swale (or bioswale) is a shallow stormwater channel that is densely planted with a variety of grasses, shrubs, and/or trees designed to slow, filter, and infiltrate stormwater runoff. Check dams can be used to improve performance and maximize infiltration, especially in steeper areas.

Figure 1 Vegetated Swale, Philadelphia, PA (USEPA, picasaweb)

Applications		**Stormwater Quantity Functions**	
Residential	Yes	Volume	Low/Med
Commercial	Yes	Groundwater Recharge	Low/Med
Ultra Urban	Limited	Peak Rate	Low/Med
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Limited	TSS	Med/High
Highway/Road	Yes	TP	Low/High
Recreational	Yes	TN	Medium
		Temperature	Medium

Additional Considerations	
Cost	Low/Med
Maintenance	Low/Med
Winter Performance	Medium

Variations

- Vegetated swale with infiltration trench
- Linear wetland swale
- Grass swale

Key Design Features

- Handles the 10-year storm event with some freeboard
- Two-year storm flows do not cause erosion
- Maximum size is five acres
- Bottom width of two to eight feet
- Side slopes from 3:1 (H:V) to 5:1
- Longitudinal slope from one to six percent
- Check dams can provide additional storage and infiltration

Site Factors

- Water table to bedrock depth: 2 foot minimum.*
- Soils: A, B preferred; C & D may require an underdrain (see infiltration BMP)
- Slope: 1 to 6 percent. (less than one percent can be used w/ infiltration)
- Potential hotspots: No
- Maximum drainage area: 5 acres

Benefits

- Can replace curb and gutter for site drainage and provide significant cost savings
- Water quality
- Peak and volume control with

Limitations

- Limited application in areas where space is a concern
- Unless designed for infiltration, there is limited peak and volume control

* four feet recommended, if possible

Description and Function

Vegetated swales are broad, shallow, earthen channels designed to slow runoff, promote infiltration, and filter pollutants and sediments in the process of conveying runoff. Water is filtered through the soil to under drains and the swale is quickly dewatered, preventing standing water. Vegetated swales are an excellent alternative to conventional curb and gutter conveyance systems, because they provide pretreatment and can distribute stormwater flows to subsequent BMPs.

Vegetated swales are sometimes used as pretreatment devices for other structural BMPs, especially from roadway runoff. While swales themselves are intended to effectively treat runoff from highly impervious surfaces, pretreatment measures are recommended to enhance swale performance. Pretreatment can dramatically extend the functional life of any BMP, as well as increase its pollutant removal efficiency by settling out some of the coarser sediments. This treatment volume is typically obtained by installing check dams at pipe inlets and/or driveway crossings. Other

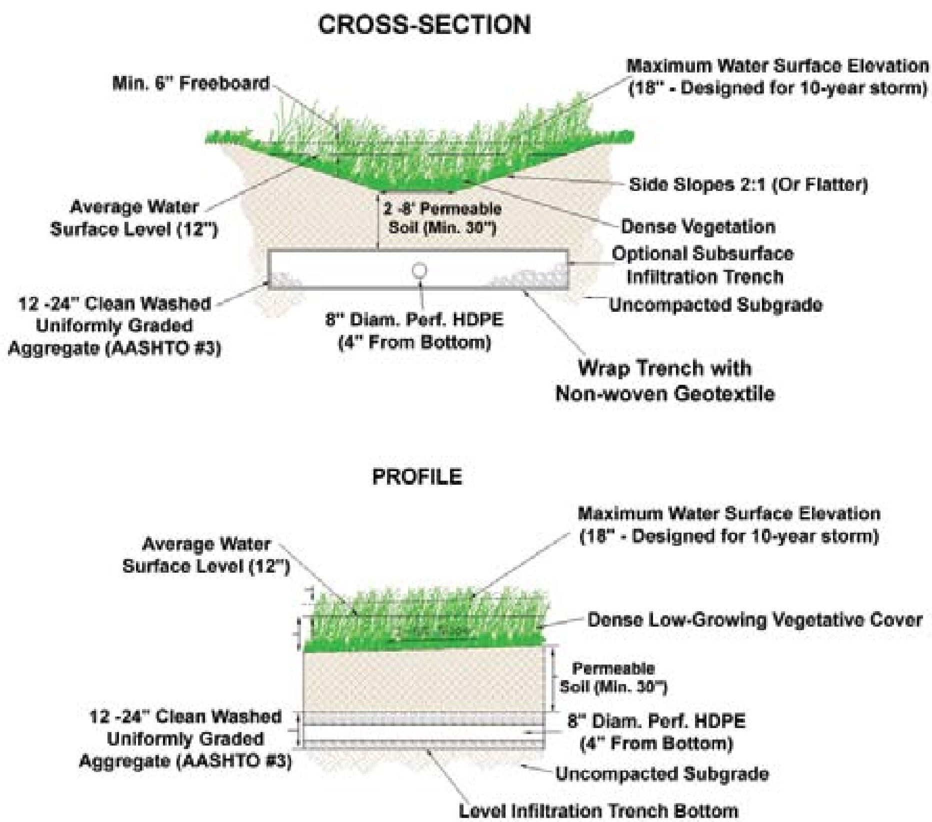

Figure 2 Schematics of Vegetated Swale with an underlying aggregate layer
Source: Pennsylvania Stormwater BMP Manual, 2006

A vegetated swale typically consists of a band of dense vegetation, underlain by at least 12 inches of permeable soil (greater than 0.5 inches/hour). Swales constructed with an underlying aggregate layer (**Figure 2)** can provide significant volume and peak rate reductions. The permeable soil media should have a minimum infiltration rate of 0.5 inches per hour.

pretreatment options include a vegetated filter strip, a sediment fore-bay (or plunge pool) for concentrated flows, or a pea gravel diaphragm (or alternative) with a six-inch drop where parking lot sheet flow is directed into a swale.

Check dams made of wood, stone, or concrete are often employed to enhance infiltration capacity, decrease runoff volume, rate, and velocity. They also promote additional filtering and settling of nutrients and other pollutants. Check-dams create a series of small, temporary pools along the length of the swale, which drain down within a maximum of 48 hours.

Weep holes may be added to a wood or concrete check dam to allow the retained volume to slowly drain out. Care should be taken to ensure that the weep holes are not subject to clogging. For stone check dams, allow lower flows (two-year storm) to drain through the stone, while allowing higher flows (10-year storm) to drain through a lower section in the center (thereby reducing the potential erosion from water flowing around the sides of the check dam). Flows through a stone check dam are a function of stone size, flow depth, flow width, and flow path length through the dam.

Conveyance

It is highly recommended that a flow splitter or diversion structure be provided to allow larger flows to bypass this practice as needed. Contributing drainage areas should be limited to five acres and an overflow should be provided within the practice to pass the excess flows to a stabilized water course or storm drain. Weirs are common overflow systems with media filters and can control velocities so that they are non-erosive at the outlet point to prevent downstream erosion.

Media filters should be equipped with a minimum eight-inch diameter underdrain in a one-foot gravel bed. Increasing the size of the underdrain makes freezing less likely. The porous gravel bed prevents standing water in the system by promoting drainage. Gravel is also less susceptible to frost heaving than finer grained media. It is also highly recommended that a permeable filter fabric be placed between the underdrain and gravel layer but not extend laterally from the pipe more than two feet on either side (**Figure 2**).

Variations

Vegetated swale with infiltration trench

This option includes a six to 24-inch aggregate bed or trench, wrapped in a nonwoven geotextile (See Infiltration BMP for further design guidelines). The addition of an aggregate bed or trench can substantially increase volume control and water quality performance although cost is also increased.

Vegetated swales with infiltration trenches are best fitted for milder sloped swales (< 1 percent) or poorly-drained soils where the addition of the aggregated bed system can help to make sure that the maximum allowable ponding time of 48 hours is not exceeded. Ideally, the subsurface system should be designed like an infiltration trench (see Infiltration Practices BMP Fact Sheet). The subsurface trench should be comprised of terraced levels, though sloping trench bottoms may also be acceptable. The storage capacity of the infiltration trench may be added to the surface storage volume to achieve the desired storage.

Grass swale

Grass swales are essentially conventional drainage ditches. They typically have milder side and longitudinal slopes than their vegetated counterparts. Grass swales are usually less expensive than vegetated swales. However, they provide far less infiltration and pollutant removal opportunities and should be used only as pretreatment for other structural BMPs. Grassed swales, where appropriate, are preferred over catch basins and pipes because of their ability to increase travel time and reduce peak flow rates from a site.

Linear wetland swale

Wetland swales occur when the water table is located very close to the surface, incorporating long, shallow, permanent pools or marshy conditions that can sustain wetland vegetation. Like the dry swale, the entire water quality treatment volume is stored within a series of cells created by check dams.

Potential Applications

1. Residential – Swales can be used along road rights of ways and for side yard and backyard drainage.

2. Commercial/Industrial – Swales can provide site drainage around a site, within a site and can help take/slow discharge from other BMPs that outlet to the swale (**Figure 3**).

3. Ultra-urban – There may be some opportunity for swales in ultra-urban areas. However, swales are usually no less than two feet deep. With horizontal to vertical side slopes between 3:1 to 5:1(horizontal to vertical), the top width of the swale can prohibit its use in this setting where space is usually at a premium.

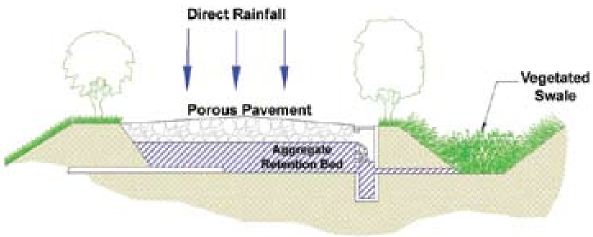

Figure 3 Slow discharge from porous pavement bed to vegetated swale
Source: Pennsylvania Stormwater BMP Manual 2006

4. Retrofit – Potential application in retrofit situations will depend strongly on space and topographic limitations. On sites with little to no slope, swales may not be the best drainage option. In these areas, swales may end up not moving water fast enough or may be prone to long periods of flooding or inundation in areas meant to be mostly dry.

5. Highway/Road – Vegetated swales are an excellent alternative to curb and gutter systems. Appropriately sized roadside swales should be able to handle all the runoff from the roadway and may also be able to handle runoff from areas outside the road surface.

Design Considerations

1. Sizing

   a. Convey the calculated peak discharge from a 10- year storm event. Use Manning's equation to calculate the velocity associated with the flow to make sure velocities are not larger than permissible velocities discussed in Technical Standards.

   b. Temporarily store and infiltrate the one-inch storm event, while providing capacity for up to the 10-year storm with 12 inches of freeboard.

   c. Flows for up to the 2-year storm should be conveyed without causing erosion.

   d. Maintain a maximum ponding depth of 18 inches at the end point of the channel, with a 12-inch average maintained throughout.

   e. The maximum ponding time should be 24 hours. It is critical that swale vegetation not be submerged during smaller storms, because it could cause the vegetation to bend over with the flow. This leads to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities.

   f. Bottom widths typically range from two to eight feet. The maximum bottom width to depth ratio for a trapezoidal swale should be 12:1.

2. Longitudinal slopes between one and six percent are recommended.

3. Swale side slopes are best within a range of 3:1 to 5:1 and should never be greater than 2:1 for ease of maintenance and side inflow from sheet flow.

4. Check dams

   a. Recommended for vegetated swales with longitudinal slopes greater than three percent or when additional detention or infiltration is desired.

   b. Should be constructed to a height of six to 18 inches and regularly spaced.

   c. Should be keyed into the bottom and sides of the swale, usually at least one to two feet on all sides. The height of the key on both sides should exceed the water surface elevation of the 10-year event by at least six inches.

d. The middle of the check dam crest should be below the sides of the check dam to help focus flow over the check dam and away from the channel sides.

5. Maximum drainage area is five acres.

6. Soil testing is required when infiltration is planned (Soil Infiltration Testing Protocol Appendix).

7. Runoff can be directed as concentrated flows or as lateral sheet flow drainage. Both are acceptable provided sufficient stabilization or energy dissipation is included. If flow is to be directed into a swale via curb cuts, provide a two- to three-inch drop at the interface of pavement and swale. Curb cuts should be at least 12 inches wide to prevent clogging and should be spaced appropriately to minimize the number of cuts but maximize area drained.

8. Soil should be at least 12 inches of loamy or sand with an infiltration rate of at least 0.5 inches per hour.

9. Inundation time is 24 hours. Rototill and replant swale if draw down time is more than 24 hours.

10. Prior to establishment of vegetation, a swale is particularly vulnerable to scour and erosion and therefore its seed bed must be protected with temporary erosion control, such as straw matting, straw-coconut matting, compost blankets, or fiberglass roving. Most vendors will provide information about the Manning's 'n' value and will specify the maximum permissible velocity. It is critical that the selected erosion control measure is adequate to prevent scour.

Stormwater Functions and Calculations

Utilize Manning's equation to calculate the velocity associated with the flow from the peak discharge of the 10 year storm or local standard. Maintain velocity of the 10 year and water quality criteria at non-erosive rates.

Manning's Equation

$$Q = VA = \frac{1.49}{n}\left(\frac{A}{WP}\right)^{2/3} S^{1/2}$$

Where;

Q = Flow in cfs
V = Velocity in ft/sec
A = Area in ft^2
n = Manning's roughness coefficient
WP = Wetted Perimeter in ft
S = Slope in ft/ft

Manning's roughness coefficient, or 'n' value in the equation, varies with the type of vegetative cover and design flow depth. Therefore, more conservative, lower numbers in the "n" value guidance tables should be used in design to determine flow velocities.

If driveways or roads cross a swale, culvert capacity may supersede Manning's equation for determination of design flow depth. In these cases, use standard culvert calculations to establish that the backwater elevation would not exceed the banks of the swale. If the maximum permissible velocity is exceeded at the culvert outlet, energy dissipation measures must be implemented.

Volume calculations (as it relates to the use of check dams)

The volume stored behind each check-dam (**Figure 4**) can be approximated from the following equation:

Storage Volume = 0.5 * (Length of Swale Impoundment Area per Check Dam) * (Depth of Check Dam) * [(Top Width of Check Dam) + (Bottom Width of Check Dam)] / 2

Active infiltration during the storm should also be accounted for when appropriate according to guidance provided in the Infiltration Practices BMP Fact Sheet.

Peak rate mitigation

Vegetated swales can help reduce peak flows by increasing travel times, reducing volume through infiltration, and storing runoff behind check dams, culverts, etc.

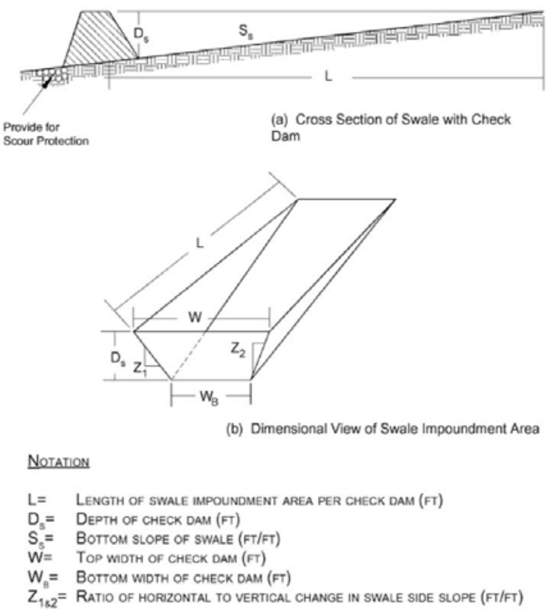

Figure 4 Storage behind check dam
Source: Northern Virginia Planning District Commission, 1992

Water quality improvement

Although the reported water quality benefits of vegetated swales vary widely, they can be expected to remove a high amount of total suspended solids (typically 70 percent to 90 percent), a low-to-medium amount of total phosphorus (approximately 10 percent to 50 percent), and a medium amount of total nitrogen (often 40 percent to 75 percent). There is some research to suggest that longer swales provide additional treatment. Vegetated swales can be used effectively for pretreatment prior to discharge to other BMPs (see Post-Construction Stormwater Management Chapter of Technical Standards for water quality criteria and calculations).

Construction Guidelines

1. Begin vegetated swale construction only when the upgradient site has been sufficiently stabilized and temporary erosion and sediment control measures are in place. Vegetated swales should be constructed and stabilized very early in the construction schedule, preferably before mass earthwork and paving increase the rate and volume of runoff.

2. Rough grade the vegetated swale. Equipment should avoid excessive compaction and/or land disturbance. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an infiltration trench is not proposed), the compacted soils should be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil should be thoroughly deep plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

3. After rough grading, fine grade the vegetated swale. Accurate grading is crucial for swales. Even the smallest non-conformities may compromise flow capacity or soil stability.

4. Vegetation should consist of a dense and diverse selection of close-growing, water-tolerant plants (See Recommended Plant List for BMPs Appendix for complete list). Common species used in vegetated swales in Michigan include Canada Bluejoint (Calamagrostis canadensis), Virginia Wild Rye (Elymus virginicus), Switch Grass (Panicum virgatum), and Prairie Cord Grass (Spartina pectinata). Additionally, a cover crop of seed oats (Avena sativa) and Annual Rye (Lolium multiforum) should be used for quick germination and stability.

Maintenance

1. Irrigation will be necessary during plant establishment and may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.

2. Stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded swales should be required for at least the first 75 days following the first storm event after planting. If runoff velocities are high, consider sodding the swale or diverting runoff until vegetation is fully established.

3. Annually inspect and correct erosion problems, damage to vegetation, and sediment and debris accumulation (address when greater than three inches at any spot or covering vegetation).

4. Annually mow and trim vegetation to ensure safety, aesthetics, proper swale operation, or to suppress weeds and invasive vegetation. Dispose of cuttings in a local composting facility; mow only when swale is dry to avoid rutting.

5. Annually inspect for uniformity in cross-section and longitudinal slope; correct as needed.

6. Inspect and correctly check dams when signs of altered water flow (channelization, obstructions, etc.) are identified.

Winter Considerations

Plowing snow into swales will help insulate the bottom of the swale. However, snow that has accumulated salt or sand from de-icing operations should not be pushed into swales. Winter conditions also necessitate additional maintenance concerns, which include the following:

1. Inspect swale immediately after the spring melt, remove residuals (e.g., sand) and replace damaged vegetation without disturbing remaining vegetation.

2. If roadside or parking lot runoff is directed to the swale, mulching and/or soil aeration/manipulation may be required in the spring to restore soil structure and moisture capacity and to reduce the impacts of de-icing agents.

3. Use nontoxic, organic de-icing agents, applied either as blended, magnesium chloride-based liquid products or as pretreated salt.

4. Consider the use of salt-tolerant vegetation in swales.

Cost

Vegetated swales provide a cost-effective alternative to traditional curbs and gutters, including associated underground storm sewers (**Table 1**). The following table compares the cost of a typical vegetated swale (15-foot top width) with the cost of traditional conveyance elements.

It is important to note that the costs listed are strictly estimates and should be used for rough estimating purposes only. Also, these costs do not include the cost of activities such as clearing, grubbing, leveling, filling, and sodding of vegetated swale (if required). When all construction, operation, and maintenance activities are considered, the cost of vegetated swale installation and maintenance is far less than that of traditional conveyance elements.

	SWALE	Underground Pipe	Curb & Gutter
Construction Cost (per linear foot)	$4.50 - $8.50 (from seed)	$2 per foot per inch of diameter	$13 - $15
	$15 - $20 (from sod)	(e.g. a 12” pipe would cost $24 per linear foot)	
Annual O & M Cost (per linear foot)	$0.75	No Data	No Data
Total annual cost (per linear foot)	$1 from seed $2 from sod	No Data	No Data
Lifetime (years)	50		20

Table 1 Cost Comparison showing vegetated swale to pipe, curb, and gutter
Source: Bay Area Stormwater Management Agencies Association, June 1997

Designer/Reviewer Checklist for Vegetated Swales

Type of vegetated swale proposed: ____

ITEM	Page No.	YES	NO	N/A	NOTES
Can the swale safely (with freeboard) convey the 10-year event? ➢ *Max. drainage area:* ***5 acres*** ➢ *Max. ponding depth at end point of channel:* ***18 inches*** ➢ *Max. ponding time:* ***24 hours***	1,4				
Are bottom slopes between one percent and six percent?	1,4				
Are check dams provided for slopes > 3%?	4				
Are check dams adequately keyed into swale bottom and sides?	4				
Are two-year and ten-year flows non-erosive?	1,4,5				
Will the swale completely drain in 48 hours?	2,3				
Are side slopes between 3:1 and 5:1 H:V?	1,3,4				
Are swale soils loam, loamy sand or sandy loam? ➢ *Min. infiltration rate of permeable media:* ***0.5 in/hr***	5				
Underdrain provided for infiltration swales? ➢ *Min. diameter of underdrain:* ***8 inches***	2,3				
Vegetation and Manning's coefficient selected?	4,6				
Non-erosive inflow condition(s)?	--				
Erosion control provided during construction?	5				
Maintenance accounted for and plan provided?	6,7				
Additional Design Factors ➢ *Hydraulic residence time no less than 5 minutes; optimal time is 9 minutes* ➢ *Average velocity no greater than 0.9 ft/sec*					

➢ *Denotes Minimum Design Considerations*

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BMP Fact Sheet

WATER QUALITY DEVICES

Various proprietary, commercially available BMPs have been designed to remove non-point source pollutants from the conveyance system for storm-water runoff. These structural BMPs vary in size and function, but all utilize some form of filtration, settling, or hydrodynamic separation to remove particulate pollutants from overland or piped flow. The devices are generally configured to remove pollutants including coarse sediment, oil and grease, litter, and debris. Some filtration devices employ additional absorbent/adsorbent material for removal of toxic pollutants. Pollutants attached to sediment such as phosphorus, nitrates, and metals may be removed from stormwater by effective filtration or settling of suspended solids. Regular maintenance is critical for the continued proper functioning of water quality devices.

Figure 1 Installation of hydrodynamic separator (Johnson County, Kansas Stormwater Management Program)

Applications		Stormwater Quantity Functions	
Residential	Yes	Volume	None
Commercial	Yes	Groundwater Recharge	None
Ultra Urban	Yes	Peak Rate	None
Industrial	Yes	Stormwater Quality Functions	
Retrofit	Yes	TSS	Varies
Highway/Road	Yes	TP	Varies
Recreational	Yes	TN	Varies
		Temperature	None

Additional Considerations	
Cost	Varies
Maintenance	Varies, but no less than two inspections and cleanings per year
Winter Performance	High

Variations

- Filtration
- Settling
- Hydrodynamic separation

Key Design Features

- Located below ground, as part of the stormwater conveyance system
- Devices may be internal to the conveyance system
- Devices may be installed in an offline configuration, so that a certain flow will be treated while allowing a surcharge flow to bypass the treatment.

Benefits

- Can be used in a variety of applications including retrofitting existing stormwater systems

Limitations

- Virtually no water quantity benefits
- Potentially high costs
- Typically require frequent maintenance

Description and Function

Water quality devices are generally proprietary, commercially available units designed to improve the quality of stormwater by removing pollutants as the stormwater flows through the system. Devices designed to reduce particulate solids may also reduce pollutants since pollutants can be bound to solid particles.

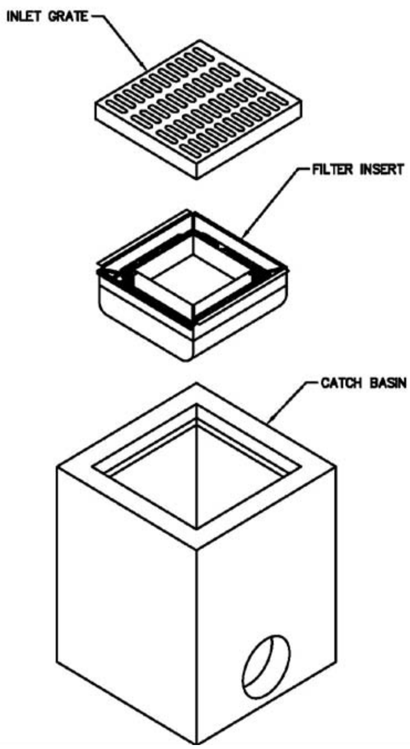


Figure 2 Tray type insert
Source: Pennsylvania Stormwater BMP Manual, 2004

Water quality devices are often employed in areas with high concentrations of pollutants in runoff and may effectively reduce sediment particles in stormwater runoff before they reach other BMPs, such as infiltration systems. Manufacturers of the devices usually provide the internal design specifications and installation instructions. Most are designed to treat a "first flush" of stormwater and provide an overflow or bypass route for large storm events. The first flush is generally measured as a volume of runoff from a specified storm.

The advantage of the manufactured devices is their adaptability to ultra urban and retrofit situations, where they can be installed beneath most surface infrastructure such as roads and parking lots.

Variations

Water quality devices may be separated into three categories: filtration (including absorption and adsorption), settling, and hydrodynamic separation.

Filtration devices

These devices usually take the form of catch basin inserts. They are installed within catch basins directly below the grates, and may be tray, bag, or basket types. Runoff passes through the device before discharging into the outlet pipe. Some modification of the catch basin inlet is sometimes necessary to accommodate and support the insert, and to allow bypass from large storms. Trays, baskets and bag type inserts perform similar functions – removing debris and sediment.

Tray type inserts

Tray type inserts (**Figure 2**) allow flow to pass through filtration media contained in a tray around the perimeter of the catch basin. High flows pass over the tray and into the catch basin directly.

Bag type inserts

Bag type inserts are made of fabric that hangs down below the catch basin grate. Overflow holes are usually provided to allow larger flows to pass without causing flooding at the grate. Certain manufactured products include polymer textiles that are intended to increase pollutant removal effectiveness.

Basket type inserts

Basket type inserts (**Figure 3**) are also installed in catch basins. Most have a handle to remove the basket for maintenance. Tray and basket inserts can

Figure 3 Catch basin insert showing basket frame
Source Stormwater 360

be fitted with packets of absorbent or adsorbent material to aid with removal of oil, grease, or toxic pollutants. Small orifices allow small storm events to weep through, while larger storms overflow the basket. Tray and basket inserts are generally useful for debris and large sediment, and require consistent maintenance.

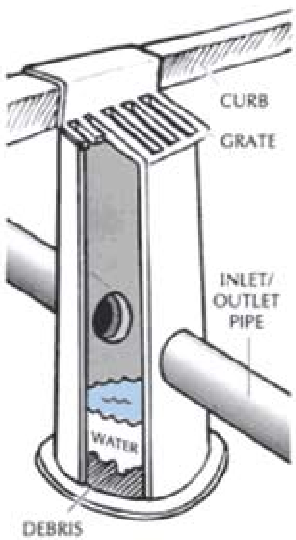


Figure 4 Sumped catch basin
Source: City of Farmington Hills, MI

Settling devices

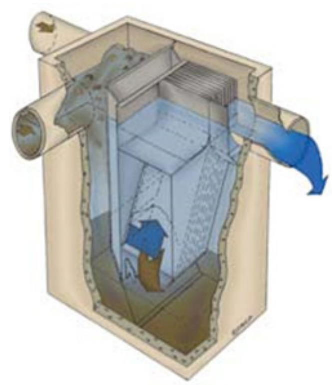
Settling devices provide sump areas where stormwater can collect within the conveyance system. Stormwater pools in the sump area, where velocity decreases and suspended solids settle out. Cleaner water pours over the top to the next link in the conveyance system. An example of a settling water quality device is a sumped catch basin.

Sumped catch basins

Sumped catch basins (**Figure 4)** are constructed in the same way as standard catch basins, but are constructed with approximately 12 to 24 inches of storage depth below the invert of the outlet pipe. Where suitable soils exist and groundwater is not a concern, weep holes should be drilled into the bottom of the inlet to prevent standing water from remaining in the inlet for long periods of time.

Hydrodynamic devices

Hydrodynamic devices (**Figure 5**) are flow-through devices designed to serve within the stormwater conveyance system. Many products available from various manufacturers employ various mechanical methods to remove sediment, debris, and pollutants from storm-water. These methods include inclined plane settlement plates, vortexes, baffle systems, tubular settlement chambers, or combinations of these. Sediment, debris, and pollutant removal efficiencies vary widely among devices and according to the rate, quantity, and quality characteristics of the flow reaching the device. These devices work most effectively in combination with other BMPs.



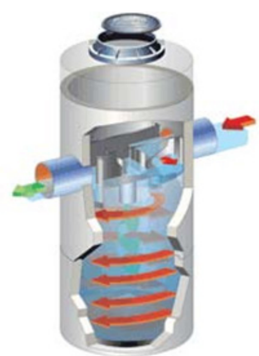


Figure 5 Example of Hydrodynamic Devices
Sources: Stormwater Solutions (top) and Terre Hill Stormwater Solutions (bottom)

Applications

The wide variety of commercially available water quality devices allows for them to be used in many different applications. However, their use in low-density residential projects is likely to be limited by their maintenance burden and the fact that other BMPs are more cost effective for stormwater management in residential projects (they are generally used for areas with high impervious cover).

Water quality devices are useful in any existing or proposed conveyance systems that have or are expected to have significant levels of sediment or debris, or in areas that have pollutant hot spots. Such areas include, but are not limited to: parking lots, gas stations, golf courses, streets, driveways, and material handling at industrial or commercial sites.

Water quality devices are commonly used as pre-treatment before other structural BMPs. Long term functionality of these devices is dependent on regular long term inspection and cleaning. Long term maintenance must be considered when specifying these devices.

Design Considerations

1. Consider the requirements of the site including anticipated sediment loading and the components of each water quality device. The proposed land use should determine specific pollutants to be removed from runoff.

2. Design to ensure easy access to the device for people and also the necessary tools for maintenance. Frequent inspection and maintenance is required. To avoid re-suspension of pollutants, perform maintenance well before sediment or debris has filled the device to capacity.

3. Consider the head requirements for the device to work properly, especially when determining the total head requirements for a treatment train. Catch basin inserts have the advantage of fitting into existing drainage systems at points where head loss already occurs.

4. The stormwater management system for the site should be designed to provide treatment for bypassed water. This occurs when storms in excess of the device's hydraulic capacity bypass the device and fail to achieve the designed runoff treatment standard for the site.

5. Properly design and select water quality devices to prevent re-suspension of captured sediments during storm events that exceed the system capacity.

Stormwater Functions and Calculations

Volume reduction

Water quality devices do not provide volume reduction.

Peak rate mitigation

Water quality devices do not provide peak rate reduction.

Water quality improvement

Water quality benefits may be quantified according to a third party review and testing of the technology, such as the U.S. EPA which offers a searchable clearinghouse of approximately 220 independent tests of BMP performance at: http://www.bmpdatabase.org/

If third party test results are not available for a device, the manufacturers' specifications and tests for removal efficiencies of a device may be considered.

For the purpose of this Technical Standards, accepted treatment rates for Water Quality Devices must be based on procedure described in the Post-Construction Stormwater Management Chapter of Technical Standards.

Winter Considerations

A limited amount of data is available concerning cold weather effects on water quality insert effectiveness. Freezing may result in runoff bypassing the treatment system. Salt stratification may also reduce detention time. Colder temperatures reduce the settling velocity of particles, which can result in fewer particles being "trapped". Salt and sand loadings may significantly increase in the winter and may warrant more frequent maintenance.

Water quality inserts (tray, bag, or basket types) as well as hydrodynamic devices should be inspected and maintained during winter months. Application of sand, ash, cinders, or other anti-skid materials may cause water quality devices to fill more quickly. Clogged inserts in cold weather can be especially problematic if flow is restricted and ponded water freezes over to create a safety hazard or render a portion of the site unusable.

Maintenance

Follow the manufacturer's guidelines for maintenance taking into account expected sediment and pollutant load and site conditions.

Inspect each water quality device at least twice per year and after all major storm events if possible. Post-construction, they should be emptied when full of sediment (and trash) and cleaned at least twice a year.

Vactor trucks may be an efficient cleaning mechanism for devices with firm or solid floors or sumps. Vactors should not be use for bag type filters or other devices where they could damage filter membranes or absorptive/adsorptive materials.

Maintenance is crucial to the effectiveness of water quality devices. The more frequent a water quality insert is cleaned, the more effective it will be. One study (Pitt, 1985) found that water quality inserts can effectively store sediment up to 60 percent of their sump volumes. Once the stored volume exceeds 60 percent, the inflow re-suspends the sediments into the stormwater. Keeping a maintenance log of sediment amounts and dates removed is helpful in planning a maintenance schedule.

Cost

Costs vary widely according to manufacturer, type, and size of water quality devices. Contact manufacturers to determine current costs.

Installation and maintenance costs for in-line or off-line devices installed below ground can run significantly higher than for vegetative filters and infiltration devices that provide similar levels of treatment.

Designer/Reviewer Checklist for Water Quality Devices

Type of water quality device(s) proposed:____

Manufacturer(s) & model(s) proposed:____

Independent Verifications (ETV, TARP, etc.):____

ITEM	Page No.	YES	NO	N/A	NOTES
If system is off-line, adequate flow diversion system?	--				
If system is on-line, adequate bypass/overflow that minimizes release of captured pollutants?	--				
Adequate hydraulic head available for device to operate?	5				
Properly sized for drainage area, flow, pollutant capture?	--				
Has device been independently verified for adequate pollutant removal for appropriate particle sizes (especially if it is the primary water quality BMP)?	4				
Manufacturer's recommendations followed?	--				
Details provided for device and connections?	--				
Erosion control provided, if necessary?	--				
Easy access/visibility for maintenance?	4				
Maintenance accounted for and a detailed plan provided (including the amount sediment/debris accumulation that triggers the need for cleaning)?	5				

References

Innovative Stormwater Treatment Technologies BMP Manual. New Hampshire Watershed Management Bureau, Watershed Assistance Section, 2002.

Pennsylvania Department of Environmental Protection. *Pennsylvania Stormwater Best Management Practices Manual*, 2006

Pitt, R. Characterizing and Controlling Urban Runoff through Street and Sewerage Cleaning. U.S. Environmental Protection Agency, June 1985.

Recommended Plant Lists for Best Management Practices

Appendix D2

RECOMMENDED PLANT LISTS FOR BEST MANAGEMENT PRACTICES

This appendix contains recommended native and non-native (when appropriate) plant species for the Best Management Practices detailed throughout the manual. The recommended list contains species that are considered suitable to conditions in Central Indiana, which is located in Ecoregion 55. Species have been recommended based on hardiness, aesthetics, functionality, and commercial availability. It is certain that species exist outside the confines of this list that will perform in a comparable way to those listed; however, commercial availability is often a limiting factor in obtaining material for native plantings. Over time, and in certain locales, additional species will become available to supplement those listed below.

An array of planting zones is provided based on normal water levels (**Figure 1**). Using these zones will provide the best chances for long-term success of native planting in the context of LID. While plants may naturally occur outside of the given ranges, these ranges are intended to be guidelines for plant installation. Whenever possible and practical in standing water conditions, native plants should be installed in live plant form (rather than seed). Seed or a combination of seed and live plants may be used in upland situations.

Recommendations are given for height, bloom color, bloom time, sun requirements, and salt tolerance. Please note that these are recommendations based on a range of situations, and a specific plant or population may vary from site-to-site. For sun requirements, F = full sun required, P = partial sun tolerated, and S = shade tolerated. Salt tolerance is classified as Yes (Y) or No (N). This was determined through literature reviews and anecdotal evidence. If there is no information confirming tolerance, a "No" was listed.

	Zone A — 2"-4" Below Water Level	Zone B — 0"-2" Below Water Level	Zone C — 0"-2" Above Water Level	Zone D — 2"-4" Above Water Level	Zone E — 4"-18" Above Water Level	Zone F — 18"+ Above Water Level	Zone G — Planter Boxes	Zone H — Vegetated Roofs
Rain gardens/Bioretention	✤	✤	✤	✤	✤	✤		
Vegetated Filter Strips			✤	✤	✤	✤		
Vegetated Swales		✤	✤	✤				
Infiltration Basin		✤	✤					
Subsurface Infiltration Basins				✤	✤	✤		
Infiltration Trenches				✤	✤	✤		
Infiltration Berns	✤	✤	✤	✤	✤	✤		
Planter Boxes							✤	
Vegetated Roofs								✤
Constructed Wetlands	✤	✤	✤	✤				
Wet Ponds	✤	✤	✤					
Dry Extended Detention Basins			✤	✤	✤	✤		
Riparian Corridor Restoration			✤	✤				
Native Revegetation	✤	✤	✤	✤	✤	✤	✤	✤

Figure 1 Planting Zone/BMP Matrix

Plant Installation

Native Seeding

Seasonal consideration: October 1-June 15 (note: seeds should not be planted on frozen ground).

Native seeding is generally recommended for areas above the water line or 1-2" below the water line. Live plant material should be used to establish vegetation at deeper water levels.

Broadcast seeding

Broadcast seeding is preferred over drill seeding on graded, bare soil sites. Apply the seed uniformly over the surface using a combination seeder/cultipacker unit such as a Brillion or Truax Trillion seeder. The Trillion seeder is preferred as it is designed to handle native seeds.

A cone seeder or other similar broadcasting equipment may also be used if the seed mix does not contain fluffy seeds in amounts sufficient to prevent free flowing without plugging. Seed should then be pressed into the surface using a cultipacker or roller.

Drill seeding

A rangeland-type no-till drill designed to plant native grasses and forbs may be used in bare soils although this equipment is specifically designed to plant through existing vegetation which is killed with an herbicide. Cultipacking or rolling before seeding may be required to prevent seed placement depths exceeding 0.25 inch, but cultipacking or rolling after seeding is not required.

All seeding equipment, whether broadcast or drill, should be calibrated to deliver the seed at the rates and proportions specified in the plans. Equipment should be operated to ensure complete coverage of the entire area to be seeded, and seed must be placed no deeper than 0.25 inch in the soil. No fertilizers or soil conditioners will be required or allowed.

Native Planting

Seasonal considerations: May 1-July 1

Plant plugs should be installed in holes drilled with an auger the same diameter and depth as the plug within +0.75 inch/- 0.25 inch. In wetland plantings where soil is soft and moist enough, a dibble bar or trowel may also be used. The planting layout should consider the requirements of the individual species regarding soil type, moisture, slope, shading, and other factors for the particular plant species.

Planting densities vary according to budget and project goals and can range from three-to-five foot spacing for plug supplements of seeded areas to six inches to two foot spacing for high visibility landscaping projects with large budgets. Groups of five-to-seven plugs of the same species planted approximately one foot apart is usually preferable to planting all species intermixed randomly across the site at a uniform density.

In wetland or shoreline areas with potential for high wave action or wildlife predation that may dislodge newly planted plugs, plugs should be secured with 6-inch or 8-inch U-shaped wire erosion control blanket staples. Staple length is determined by the density of the planting substrate; softer substrates require longer length to hold plugs adequately.

In areas where potential for wildlife predation exists, such as retention basins or other planting areas adjacent to open water, waterfowl barriers should be installed around a minimum of 50 percent of the plugs. All plugs not protected by barriers should be stapled into the substrate as described above. Barriers may consist of plastic or wire mesh enclosures supported with wooden stakes, adequately constructed to inhibit access by waterfowl for one growing season. Enclosures should extend at least two feet above the plant tops. Methodology should be approved by the project designer with input from a restoration ecologist if necessary. Barriers may be removed after one growing season.

Tree and Shrub Planting

See "Planting & Transplanting Landscape Trees & Shrubs" from the Purdue University Cooperative Extension Service – Department of Horticulture, Publication HO-100-W.

Maintenance and Management

Maintaining vegetated BMPs is typically most important during the first few years following installation. Supplemental irrigation may be needed to help establish plants in drought conditions. Plants may need to be replaced due to predation or other unseen factors. Most commonly, management includes removing invasive species via mowing, hand-pulling, or spot herbicide applications. In larger areas, broadcast herbicide applications may be appropriate. Over time in upland areas, controlled burning may be used as a way to invigorate the plantings and control certain invasive species. If not feasible for social or cultural reasons, an annual or biennial mowing may be used instead of fire.

Long-term management may be necessary, but is typically significantly less intensive. The site should be periodically checked for invasive species infestations. Any prairie or open area may need occasional (every three to five years) burning or mowing to remove woody vegetation that may encroach.

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Zone A

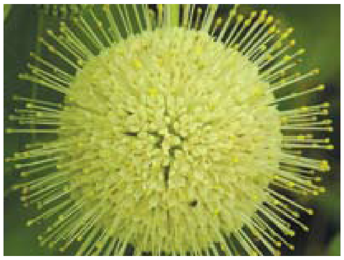
Planting Zone = Two-to-four inches below water level

These species require continual inundation within the given water depths in order to thrive. Although slight, short-term variances may be tolerated (± five inches for a period of 48 hours or less), water levels must remain in this range for a majority of the growing season for maximum plant growth and survival.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
Cephalanthus occidentalis	Buttonbush	15’	White	Jun-Aug	F/P/S	N
Grasses/Sedges/Rushes:						
Acorus calamus	Sweet flag	1’-4’	Green	May-Jun	F/P	N
Scirpus acutus	Hard-stemmed bulrush	4’-6’	Brown	Apr-Aug	F	Y
Scirpus validus	Great bulrush	4’-8’	Brown	May-Aug	F	Y
Sparganium americanum	American bur reed	2’-5’	Green	Jun-Aug	F/P	N
Sparganium eurycarpum	Common bur reed	2’-6’	Green	May-Aug	F	N
Forbs:						
Asclepias incarnata	Swamp milkweed	3’-5’	Pink	Jun-Sep	F/P	N
Decodon verticillatus	Swamp loosestrife	2’-4’	Purple	Jul-Sep	F/P	N
Iris virginica	Blue flag iris	2’-3’	Purple	May-Jul	F/P/S	N
Peltandra virginica	Arrow arum	2’-5’	Green	Jun-Jul	F/P/S	N
Pontedaria cordata	Pickerelweed	1’-3’	Violet	Jun-Sep	F/P	N
Sagittaria latifolia	Arrowhead	1’-4’	White	Jun-Sep	F/P	N

Representative Zone A Species

Buttonbush



Pickerel Weed

Swamp Milkweed

Arrowhead

Blue Flag Iris

Source: JFNew

Zone B

Planting Zone = Zero-to-two inches below water level

These species tolerate fluctuating water levels within this range. Although slight, short-term variances may be tolerated (± five inches for a period of 48 hours or less), water levels must remain in this range for most of the growing season for maximum plant growth and survival.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
Cephalanthus occidentalis	Buttonbush	15’	White	Jun-Aug	F/P/S	N
Grasses/Sedges/Rushes:						
Acorus calamus	Sweet flag	1’-4’	Green	May-Jun	F/P	N
Carex comosa	Bristly sedge	2’-3’	Green	May-Jun	F	N
Carex lacustris	Lake sedge	2’-4’	Brown	May-Jun	F/P/S	N
Carex stricta	Tussock sedge	2’-3’	Brown	Apr-Jun	F/P	N
Eleocharis acicularis	Needle spike rush	6”	Green	May-Oct	F	N
Eleocharis obtusa	Blunt spike rush	1’-2’	Green	May-Sep	F/P	N
Glyceria striata	Fowl manna grass	1’-5’	Green	May-Jun	F/P/S	N
Juncus effusus	Soft rush	1’-4’	Brown	July	F/P	N
Scirpus acutus	Hard-stemmed bulrush	4’-6’	Brown	Apr-Aug	F	Y
Scirpus cyperinus	Wool grass	3’-5’	Tan	Jun-Sep	F	Y
Scirpus pendulus	Red bulrush	2’-4’	Brown	May-Jun	F	N
Scirpus validus	Great bulrush	4’-8’	Brown	May-Aug	F	Y
Sparganium americanum	American bur reed	2’-5’	Green	Jun-Aug	F/P	N
Sparganium eurycarpum	Common bur reed	2’-6’	Green	May-Aug	F	N
Forbs:						
Alisma plantago-aquatica	Water plantain	2’-4’	White	Jul-Sep	F	N
Asclepias incarnata	Swamp milkweed	3’-5’	Pink	Jun-Sep	F/P	N
Decodon verticillatus	Swamp loosestrife	2’-4’	Purple	Jul-Sep	F/P	N
Iris virginica	Blue flag iris	2’-3’	Purple	May-Jul	F/P/S	N
Peltandra virginica	Arrow arum	2’-5’	Green	Jun-Jul	F/P/S	N
Pontedaria cordata	Pickerelweed	1’-3’	Violet	Jun-Sep	F/P	N
Sagittaria latifolia	Arrowhead	1’-4’	White	Jun-Sep	F/P	N
Saururus cernuus	Lizard’s tail	2’-4’	White	Jun-Aug	P/S	N

Representative Zone B Species

Blue Flag Iris

Arrowhead

Bristly Sedge

Pickerel Weed

Swamp Milkweed

Source: JFNew

Zone C

Planting Zone = Zero-to-two inches above water level

These plants are tolerant of fluctuating water levels within this range. They will also tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
Acer rubrum	Red maple	90’	Green/ red	Mar-May	F/P/S	N
Alnus rugosa	Speckled alder	25’	Brown	Mar-May	F/P	N
Amelanchier arborea	Downy serviceberry	40’	White	April	F/P/S	N
Aronia prunifolia	Purple chokeberry	10’	White	Apr-Jul	F/P	N
Betula alleghaniensis	Yellow birch	100’	Purple/ Yellow	Apr-May	P/S	N
Betula papyrifera	Paper birch	70’	Brown	Apr-May	F/P	N
Cephalanthus occidentalis	Buttonbush	15’	White	Jun/Aug	F/P/S	N
Cornus amomum	Silky dogwood	10’	White	May-Jul	F/P	N
Cornus sericea	Red-osier dogwood	10’	White	May-Sep	F/P	N
Ilex verticillata	Winterberry	10’	White	June	F/P/S	Y
Larix laricina	American larch	75’	Brown	May	F/P	N
Lindera benzoin	Spicebush	15’	Yellow	Apr-May	P/S	N
Morus rubra	Red mulberry	50’	Green	May-Jun	F/P/S	N
Nyssa sylvatica	Black gum	100’	Green	May-Jul	F/P/S	Y
Physocarpus opulifolius	Ninebark	10’	White	May-Jun	F/P	N
Picea mariana	Black spruce	60’	Brown	May-Jun	F/P/S	N
Quercus bicolor	Swamp white oak	70’	Green/ yellow	May	F/P/S	Y
Quercus palustris	Pin oak	90’	Green/ yellow	Apr-May	F/P/S	Y
Ribes americanum	Wild black currant	5’	Yellow	Apr-Jun	F/P/S	N
Rosa palustris	Swamp rose	2’-7’	Pink	Jun-Aug	F/P/S	N
Thuja occidentalis	White cedar	50’	Brown	Apr-May	F/P/S	N
Ulmus americana	American elm	100’	Brown	Mar-Apr	F/P/S	N
Ulmus rubra	Slippery elm	80’	Green	Mar-Apr	F/P/S	N
Viburnum lentago	Nannyberry	20’	White	Apr-Jun	P/S	Y
Grasses/Sedges/Rushes:						
Calamagrostis canadensis	Blue joint grass	2’-4’	Brown	June	F/P	N
Carex comosa	Bristly sedge	2’-3’	Green	May-June	F/P	N
Carex crinita	Fringed sedge	2’-5’	Green	May	F/P/S	N
Carex hystericina	Porcupine sedge	2’-3’	Green	May-June	F/P/S	N
Carex lupulina	Common hop sedge	2’-3’	Green/ Brown	May-June	F/P/S	N
Carex muskingumensis	Palm sedge	1’-2’	Brown	May-June	S	N
Carex stipata	Common fox sedge	1’-3’	Brown	Apr-May	F/P/S	N
Carex stricta	Tussock sedge	2’-3’	Brown	Apr-Jun	F/P	N
Carex vulpinoidea	Brown fox sedge	2’-3’	Brown	May-Jun	F/P	N
Cinna arundinacea	Common wood reed	3’-4’	Green	Aug-Sep	P/S	N
Eleocharis acicularis	Needle spike rush	6”	Green	May-Oct	F	N
Eleocharis obtusa	Blunt spike rush	1’-2’	Green	May-Sep	F/P	N
Glyceria striata	Fowl manna grass	1’-5’	Green	May-Jun	F/P/S	N
Juncus effusus	Soft rush	1’-4’	Brown	July	F/P	N
Juncus tenuis	Path rush	6”-2’	Brown	June	F/P/S	N
Juncus torreyi	Torrey’s rush	1’-2’	Brown	Jun-Sep	F	Y
Scirpus acutus	Hard-stemmed bulrush	4’-6’	Brown	Apr-Aug	F	Y
Scirpus atrovirens	Dark green rush	3’-5’	Brown	Jun-Aug	F	N
Scirpus cyperinus	Wool grass	3’-5’	Tan	Jun-Sep	F	Y
Scirpus pendulus	Red bulrush	2’-4’	Brown	May-Jun	F	N
Scirpus validus	Great bulrush	4’-8’	Brown	May-Aug	F	Y

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Forbs:						
Alisma plantago-aquatica	Water plantain	2'-4'	White	Jul-Sep	F	N
Anemone canadensis	Canada anemone	1'-2'	White	May-Sep	F/P	N
Angelica atropurpurea	Great angelica	6'-9'	White	May-Jun	F/P	N
Asclepias incarnata	Swamp milkweed	3'-5'	Pink	Jun-Sep	F/P	N
Aster novae-angliae	New England aster	3'-6'	Violet	Jul-Oct	F/P	N
Aster puniceus	Swamp aster	3'-6'	Lav/ White	Aug-Oct	F	Y
Aster umbellatus	Flat-topped aster	1'-4'	White	Jul-Oct	F/P	N
Cassia hebecarpa	Wild senna	3'-5'	Yellow	Jul-Aug	F/P	N
Chelone glabra	Turtlehead	2'-4'	Cream	Aug-Sep	F/P/S	N
Eupatorium maculatum	Spotted Joe-pye weed	4'-7'	Pink	Jun-Oct	F/P	N
Eupatorium perfoliatum	Boneset	3'-5'	White	Jul-Oct	F/P	Y
Euthamia graminifolia	Grass-leaved goldenrod	1'-4'	Yellow	Jul-Sep	F/P	N
Gentiana andrewsii	Bottle gentian	1'-3'	Blue	Aug-Oct	F/P	N
Helenium autumnale	Sneezeweed	3'-5'	Yellow	Jul-Nov	F/P	Y
Helianthus giganteus	Tall sunflower	5'-12'	Yellow	Jul-Sep	F/P	N
Iris virginica	Blue flag iris	2'-3'	Purple	May-Jul	F/P/S	N
Liatris spicata	Marsh blazing star	3'-5'	Pink	Jul-Sep	F/P	N
Lilium michiganense	Michigan lily	3'-8'	Orange	Jul-Aug	P/S	N
Lobelia cardinalis	Cardinal flower	2'-5'	Red	Jul-Oct	F/P/S	N
Lobelia siphilitica	Great blue lobelia	1'-4'	Blue	Jul-Oct	F/P/S	N
Lobelia spicata	Pale spiked lobelia	1'-3'	Lavender	May-Aug	F/P	N
Mimulus ringens	Monkeyflower	2'-4'	Lavender	Jun-Sep	F/P	N
Physostegia virginiana	Obedient plant	2'-5'	Pink	Aug-Oct	F	Y
Pycnanthemum virginianum	Mountain mint	1'-3'	White	Jun-Oct	F/P	N
Rudbeckia laciniata	Cutleaf coneflower	3'-10'	Yellow	Jul-Nov	F/P/S	N
Sagittaria latifolila	Arrowhead	1'-4'	White	Jun-Sep	F/P	N
Saururus cernuus	Lizard's tail	2'-4'	White	Jun-Aug	P/S	N
Sisyrinchium angustifolium	Stout blue-eyed grass	1'	Blue	May-Aug	F/P	N
Solidago ohiensis	Ohio goldenrod	2'-3'	Yellow	Jul-Oct	F/P	N
Solidago patula	Swamp goldenrod	3'-6'	Yellow	Aug-Oct	F/P/S	N
Solidago riddellii	Riddell's goldenrod	2'-5'	Yellow	Sep-Nov	F	N
Spiraea alba	Meadowsweet	3'-6'	White	June-Sep	F/P	Y
Spiraea tomentosa	Steeplebush	2'-5'	Pink	Jul-Sep	F/P	Y
Thalictrum dasycarpum	Purple meadow-rue	3'-6'	Cream	May-Jul	F/P	N
Verbena hastata	Blue vervain	3'-6'	Violet	Jun-Sep	F	N
Vernonia missurica	Missouri ironweed	3'-5'	Purple	Jul-Sep	F	N
Zizia aurea	Golden Alexanders	1'-3'	Yellow	Apr-Jun	F/P/S	Y

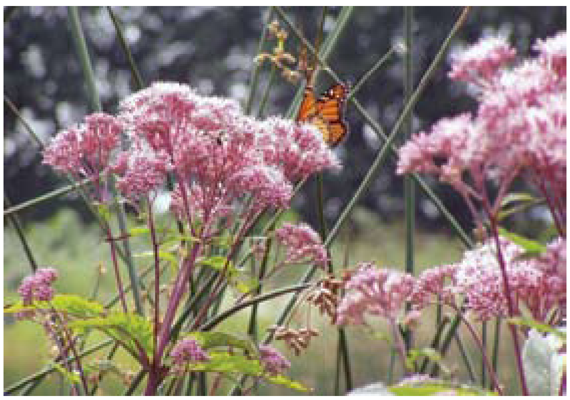
Representative Zone C Species

Cardinal Flower

Swamp Milkweed

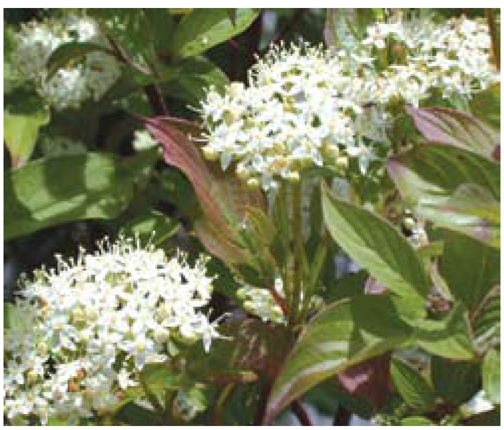
Blue-Eyed Grass

Path Rush



Joe-Pye Weed

Obedient Plant



Red-Osier Dogwood

Monkey Flower

Source: JFNew

Zone D

Planting Zone = Two-to-four inches above water level

These plants tolerate fluctuating water levels within this range. They will also tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
Acer rubrum	Red maple	90’	Green/ red	Mar-May	F/P/S	N
Acer saccharinum	Silver Maple	100’	Yellow	Mar-Apr	F/P	N
Amelanchier arborea	Downy serviceberry	40’	White	April	F/P/S	N
Aronia prunifolia	Purple chokeberry	10’	White	Apr-Jul	F/P	N
Betula alleghaniensis	Yellow birch	100’	Purple/ Yellow	Apr-May	P/S	N
Betula papyrifera	Paper birch	70’	Brown	Apr-May	F/P	N
Celtis occidentalis	Hackberry	60’	Green	May	F/P/S	N
Cercis canadensis	Redbud	25’	Red	Apr-May	F/P/S	N
Cornus amomum	Silky dogwood	10’	White	May-Jul	F/P	N
Cornus sericea	Red-osier dogwood	10’	White	May-Sep	F/P	N
Corylus americana	American hazelnut	10’	Yellow	Apr-May	F/P	N
Ilex verticillata	Winterberry	10’	White	June	F/P/S	Y
Juglans nigra	Black walnut	90’	Green	May	F/P	N
Juniperus virginiana	Red-cedar	50’	Brown	Apr-May	F/P	N
Larix laricina	American larch	75’	Brown	May	F/P	N
Lindera benzoin	Spicebush	15’	Yellow	Apr-May	P/S	N
Liriodendron tulipifera	Tulip tree	110’	Green	May-Jun	F/P	N
Morus rubra	Red mulberry	50’	Green	May-Jun	F/P/S	N
Nyssa sylvatica	Black gum	100’	Green	May-Jul	F/P/S	Y
Physocarpus opulifolius	Ninebark	10’	White	May-Jun	F/P	N
Picea mariana	Black spruce	60’	Brown	May-Jun	F/P/S	N
Platanus occidentalis	Sycamore	100’	Green	May	F/P	N
Quercus bicolor	Swamp white oak	70’	Green/ yellow	May	F/P/S	N
Quercus macrocarpa	Bur oak	85’	Yellow	May-Jun	F/P/S	N
Quercus palustris	Pin oak	90’	Green/ yellow	Apr-May	F/P/S	Y
Ribes americanum	Wild black currant	5’	Yellow	Apr-Jun	F/P/S	N
Rosa carolina	Pasture rose	3’	Pink	Jun-Sep	F/P	N
Rosa palustris	Swamp rose	2’-7’	Pink	Jun-Aug	F/P/S	N
Thuja occidentalis	White cedar	50’	Brown	Apr-May	F/P/S	N
Tilia americana	Basswood	100’	White	Jun-Jul	F/P/S	N
Tsuga canadensis	Hemlock	100’	Brown	Apr-May	F/P/S	N
Ulmus americana	American elm	100’	Brown	Mar-Apr	F/P/S	N
Ulmus rubra	Slippery elm	80’	Green	Mar-Apr	F/P/S	N
Viburnum dentatum	Arrowwood	10’	White	May-Jun	F/P/S	N
Viburnum lentago	Nannyberry	20’	White	Apr-Jun	P/S	Y
Viburnum prunifolium	Black haw	10’	White	Apr-May	F/P	N
Viburnum trilobum	Cranberry Viburnum	10’	White	Apr-May	F/P/S	N
Grasses/Sedges/Rushes:						
Andropogon gerardii	Big bluestem	4’-8’	Purple	Jul-Sep	F	N
Calamagrostis canadensis	Blue joint grass	2’-4’	Brown	June	F/P	N
Carex comosa	Bristly sedge	2’-3’	Green	May-June	F/P	N
Carex crinita	Fringed sedge	2’-5’	Green	May	F/P/S	N
Carex hystericina	Porcupine sedge	2’-3’	Green	May-June	F/P/S	N
Carex lupulina	Common hop sedge	2’-3’	Green/ Brown	May-June	F/P/S	N
Carex muskingumensis	Palm sedge	1’-2’	Brown	May-June	S	N
Carex stipata	Common fox sedge	1’-3’	Brown	Apr-May	F/P/S	N
Carex stricta	Tussock sedge	2’-3’	Brown	Apr-Jun	F/P	N
Carex vulpinoidea	Brown fox sedge	2’-3’	Brown	May-Jun	F/P	N
Cinna arundinacea	Common wood reed	3’-4’	Green	Aug-Sep	P/S	N
Elymus canadensis	Canada wild rye	3’-6’	Green	Jun-Sep	F/P	N

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Glyceria striata	Fowl manna grass	1'-5'	Green	May-Jun	F/P/S	N
Juncus tenuis	Path rush	6"-2'	Brown	June	F/P/S	N
Juncus torreyi	Torrey's rush	1'-2'	Brown	Jun-Sep	F	Y
Panicum virgatum	Switch grass	3'-5'	Green/ Purple	Jun-Oct	F/P	Y
Scirpus atrovirens	Dark green rush	3'-5'	Brown	Jun-Aug	F	N
Scirpus cyperinus	Wool grass	3'-5'	Tan	Jun-Sep	F	Y
Scirpus pendulus	Red bulrush	2'-4'	Brown	May-Jun	F	N
Spartina pectinata	Prairie cordgrass	6'-7'	Green	Jul-Aug	F	Y
Forbs:						
Anemone canadensis	Canada anemone	1'-2'	White	May-Sep	F/P	N
Angelica atropurpurea	Great angelica	6'-9'	White	May-Jun	F/P	N
Asclepias incarnata	Swamp milkweed	3'-5'	Pink	Jun-Sep	F/P	N
Aster novae-angliae	New England aster	3'-6'	Violet	Jul-Oct	F/P	N
Aster puniceus	Swamp aster	3'-6'	Lav/ White	Aug-Oct	F	Y
Aster umbellatus	Flat-topped aster	1'-4'	White	Jul-Oct	F/P	N
Cacalia atriplicifolia	Pale Indian plantain	3'-8'	White	Jun-Oct	F/P/S	N
Cassia hebecarpa	Wild senna	3'-5'	Yellow	Jul-Aug	F/P	N
Chelone glabra	Turtlehead	2'-4'	Cream	Aug-Sep	F/P/S	N
Coreopsis tripteris	Tall coreopsis	4'-8'	Yellow	Aug-Sep	F/P	N
Desmodium canadense	Showy tick-trefoil	2'-5'	Purple	Jun-Sep	F/P	N
Eryngium yuccifolium	Rattlesnake master	3'-5'	White	Jul-Sep	F	N
Eupatorium maculatum	Spotted Joe-pye weed	4'-7'	Pink	Jun-Oct	F/P	N
Eupatorium perfoliatum	Boneset	3'-5'	White	Jul-Oct	F/P	Y
Euthamia graminifolia	Grass-leaved goldenrod	1'-4'	Yellow	Jul-Sep	F/P	N
Gentiana andrewsii	Bottle gentian	1'-3'	Blue	Aug-Oct	F/P	N
Helenium autumnale	Sneezeweed	3'-5'	Yellow	Jul-Nov	F/P	Y
Helianthus giganteus	Tall sunflower	5'-12'	Yellow	Jul-Sep	F/P	N
Heliopsis helianthoides	False sunflower	4'-6'	Yellow	Jun-Oct	F/P	N
Iris virginica	Blue flag iris	2'-3'	Purple	May-Jul	F/P/S	N
Liatris spicata	Marsh blazing star	3'-5'	Pink	Jul-Sep	F/P	N
Lilium michiganense	Michigan lily	3'-8'	Orange	Jul-Aug	P/S	N
Lobelia cardinalis	Cardinal flower	2'-5'	Red	Jul-Oct	F/P/S	N
Lobelia siphilitica	Great blue lobelia	1'-4'	Blue	Jul-Oct	F/P/S	N
Lobelia spicata	Pale spiked lobelia	1'-3'	Lavender	May-Aug	F/P	N
Mimulus ringens	Monkeyflower	2'-4'	Lavender	Jun-Sep	F/P	N
Monarda fistulosa	Wild bergamot	2'-5'	Lavender	Jul-Sep	F/P	N
Physostegia virginiana	Obedient plant	2'-5'	Pink	Aug-Oct	F	Y
Polygonatum biflorum	Solomon seal	1'-4'	Green/ White	May/Jul	P/S	N
Pycnanthemum virginianum	Mountain mint	1'-3'	White	Jun-Oct	F/P	N
Rudbeckia laciniata	Cutleaf coneflower	3'-10'	Yellow	Jul-Nov	F/P/S	N
Rudbeckia triloba	Three-lobed coneflower	2'-5'	Yellow	Aug-Oct	F/P	N
Solidago caesia	Bluestem goldenrod	1'-2'	Yellow	Sep-Oct	P/S	N
Solidago flexicaulis	Zigzag goldenrod	1'-3'	Yellow	Aug/Oct	P/S	N
Solidago ohiensis	Ohio goldenrod	2'-3'	Yellow	Jul-Oct	F/P	N
Solidago patula	Swamp goldenrod	3'-6'	Yellow	Aug-Oct	F/P/S	N
Solidago riddellii	Riddell's goldenrod	2'-5'	Yellow	Sep-Nov	F	N
Spiraea alba	Meadowsweet	3'-6'	White	June-Sep	F/P	Y
Spiraea tomentosa	Steeplebush	2'-5'	Pink	Jul-Sep	F/P	Y
Thalictrum dasycarpum	Purple meadow-rue	3'-6'	Cream	May-Jul	F/P	N
Verbena hastata	Blue vervain	3'-6'	Violet	Jun-Sep	F	N
Vernonia missurica	Missouri ironweed	3'-5'	Purple	Jul-Sep	F	N
Veronicastrum virginicum	Culver's root	3'-6'	White	Jun-Aug	F/P	N
Zizia aurea	Golden Alexanders	1'-3'	Yellow	Apr-Jun	F/P/S	Y

Representative Zone D Species

Big Bluestem

Marsh Blazing Star

Wild Columbine

Great Blue Lobelia

Michigan Lily

Virginia Mountain Mint

Meadowsweet

Blue Vervain

Source: JFNew

Zone E

Planting Zone = Four-to-18 inches above water level

These plants tolerate fluctuating water levels within this range. They will also tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
Acer rubrum	Red maple	90’	Green/red	Mar-May	F/P/S	N
Acer saccharum	Sugar maple	100’	Green	Apr-May	F/P/S	N
Acer saccharinum	Silver Maple	100’	Yellow	Mar-Apr	F/P	N
Amelanchier arborea	Downy serviceberry	40’	White	April	F/P/S	N
Aronia prunifolia	Purple chokeberry	10’	White	Apr-Jul	F/P	N
Betula papyrifera	Paper birch	70’	Brown	Apr-May	F/P	N
Carya ovata	Shagbark hickory	80’	Green	May-Jun	F/P/S	N
Ceanothus americanus	New Jersey tea	1’-3’	White	Jun-Oct	F/P	N
Celtis occidentalis	Hackberry	60’	Green	May	F/P/S	N
Cercis canadensis	Redbud	25’	Red	Apr-May	F/P/S	N
Cornus amomum	Silky dogwood	10’	White	May-Jul	F/P	N
Cornus florida	Flowering dogwood	30’	White	May-Jun	F/P/S	N
Cornus sericea	Red-osier dogwood	10’	White	May-Sep	F/P	N
Corylus americana	American hazelnut	10’	Yellow	Apr-May	F/P	N
Gymnocladus dioicus	Kentucky coffee tree	85’	White	Jun	F/P	N
Juglans nigra	Black walnut	90’	Green	May	F/P	N
Juniperus virginiana	Red-cedar	50’	Brown	Apr-May	F/P	N
Larix laricina	American larch	75’	Brown	May	F/P	N
Lindera benzoin	Spicebush	15’	Yellow	Apr-May	P/S	N
Liriodendron tulipifera	Tulip tree	110’	Green	May-Jun	F/P	N
Morus rubra	Red mulberry	50’	Green	May-Jun	F/P/S	N
Nyssa sylvatica	Black gum	100’	Green	May-Jul	F/P/S	Y
Physocarpus opulifolius	Ninebark	10’	White	May-Jun	F/P	N
Picea mariana	Black spruce	60’	Brown	May-Jun	F/P/S	N
Pinus banksiana	Jack pine	60’	Brown	May-Jun	F/P	N
Pinus resinosa	Red pine	100’	Brown	Apr-May	F/P	N
Pinus strobus	White pine	100’	Brown	Jun	F/P/S	N
Platanus occidentalis	Sycamore	100’	Green	May	F/P	N
Prunus americana	American plum	30’	Red	Apr-May	F/P	N
Prunus virginiana	Choke cherry	30’	White	May-Jun	F/P/S	N
Quercus bicolor	Swamp white oak	70’	Green/yellow	May	F/P/S	N
Quercus macrocarpa	Bur oak	85’	Yellow	May-Jun	F/P/S	N
Quercus palustris	Pin oak	90’	Green/yellow	Apr-May	F/P/S	Y
Quercus rubra	Red Oak	90’	Green	May-Jun	F/P/S	N
Ribes americanum	Wild black currant	5’	Yellow	Apr-Jun	F/P/S	N
Rosa carolina	Pasture rose	3’	Pink	Jun-Sep	F/P	N
Tilia americana	Basswood	100’	White	Jun-Jul	F/P/S	N
Thuja occidentalis	White cedar	50’	Brown	Apr-May	F/P/S	N
Tsuga canadensis	Hemlock	100’	Brown	Apr-May	F/P/S	N
Ulmus americana	American elm	100’	Brown	Mar-Apr	F/P/S	N
Ulmus rubra	Slippery elm	80’	Green	Mar-Apr	F/P/S	N
Viburnum acerifolium	Maple-leaved Viburnum	7’	White	May-Aug	F/P	N
Viburnum dentatum	Arrowwood	10’	White	May-Jun	F/P/S	N
Viburnum prunifolium	Black haw	10’	White	Apr-May	F/P	N
Grasses/Sedges/Rushes:						
Andropogon gerardii	Big bluestem	4’-8’	Purple	Jul-Sep	F	N
Carex bicknellii	Copper-shouldered oval sedge	1’-2’	Brown	May-Jun	F	N
Carex muhlenbergii	Sand bracted sedge	1’-3’	Brown	May-Jun	F/P/S	N
Elymus canadensis	Canada wild rye	3’-6’	Green	Jun-Sep	F/P	N

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Elymus hystrix	Bottlebrush Grass	3'-5'	Green	Jun-Jul	P/S	N
Elymus virginicus	Virginia wild rye	2'-4'	Green	Jun	F/P/S	N
Eragrostis spectabilis	Purple love grass	1'-2'	Purple	Aug-Oct	F	N
Juncus tenuis	Path rush	6"-2'	Brown	June	F/P/S	N
Panicum virgatum	Switch grass	3'-6'	Green/ Purple	Jun-Oct	F/P	Y
Schizachyrium scoparium	Little bluestem	2'-4'	Brown	Aug-Sep	F/P	Y
Sorghastrum nutans	Indian grass	4'-9'	Green	Aug-Sep	F	N
Spartina pectinata	Prairie cordgrass	6'-7'	Green	Jul-Aug	F	Y
Stipa spartea	Porcupine grass	2'-4'	Green	Aug-Sep	F	Y
Forbs:						
Allium cernuum	Nodding wild onion	1'-2'	Lavender	Jun-Oct	F/P	N
Aquilegia canadensis	Wild columbine	1'-3'	Red/ Yellow	Apr-Jun	F/P/S	Y
Asclepias syriaca	Common milkweed	2'-4'	Pink	Jun-Aug	F/P	N
Asclepias tuberosa	Butterflyweed	1'-3'	Orange	Jun-Sep	F/P	Y
Asclepias verticillata	Whorled milkweed	1'-2'	White	Jun-Sep	F/P	N
Aster cordifolius	Heart-leaved aster	2'-4'	Blue/ White	Sep-Oct	P/S	N
Aster laevis	Smooth aster	3'-5'	Blue	Aug-Oct	F	Y
Aster lateriflorus	Calico aster	1'-3'	White	Jul-Oct	F/P/S	N
Aster macrophyllus	Big-leaved aster	6"-2'	Lav/ White	Jul-Oct	P/S	N
Aster novae-angliae	New England aster	3'-6'	Violet	Jul-Oct	F/P	N
Aster oolentangiensis	Sky-blue aster	1'-4'	Blue	Jul-Nov	F/P	Y
Aster shortii	Short's aster	1'-4'	Blue	Aug-Oct	P/S	N
Cacalia atriplicifolia	Pale Indian plantain	3'-8'	White	Jun-Oct	F/P/S	N
Campanula americana	Tall bellflower	2'-6'	Blue	Jul-Nov	P/S	N
Cassia hebecarpa	Wild senna	3'-5'	Yellow	Jul-Aug	F/P	N
Clematis virginiana	Virgin's bower	9' long	White	Jul-Aug	F/P	N
Coreopsis tripteris	Tall coreopsis	4'-8'	Yellow	Aug-Sep	F/P	N
Desmodium canadense	Showy tick-trefoil	2'-5'	Purple	Jun-Sep	F/P	N
Echinacea pallida	Purple coneflower	2'-5'	Lavender	May-Aug	F	N
Eryngium yuccifolium	Rattlesnake master	3'-5'	White	Jul-Sep	F	N
Eupatorium purpureum	Purple Joe-pye weed	3'-6'	Pink	Jul-Sep	P	N
Euphorbia corollata	Flowering spurge	2'-4'	White	May-Oct	F/P	N
Geranium maculatum	Wild geranium	1'-2'	Pink	Apr-Jul	F/P/S	N
Helianthus divaricatus	Woodland sunflower	2'-6'	Yellow	Jun-Sep	P/S	N
Helianthus giganteus	Tall sunflower	5'-12'	Yellow	Jul-Sep	F/P	N
elianthus pauciflorus	Prairie sunflower	3'-5'	Yellow	Jul-Oct	F	N
Heliopsis helianthoides	False sunflower	4'-6'	Yellow	Jun-Oct	F/P	N
Lespedeza capitata	Round-headed bush clover	2'-4'	Green	Jul-Sep	F/P	N
Liatris aspera	Rough blazing star	2'-3'	Violet	Jul-Nov	F/P	Y
Liatris spicata	Marsh blazing star	3'-5'	Pink	Jul-Sep	F/P/S	N
Liatris scariosa	Savanna blazing star	3'-5'	Violet	Aug-Oct	F/P	N
Monarda fistulosa	Wild bergamot	2'-5'	Lavender	Jul-Sep	F/P	N
Penstemon digitalis	Foxglove beardtongue	2'-4'	White	May-Jul	F/P	N
Penstemon hirsutus	Hairy beardtongue	1'-2'	Purple	May-Jul	F/P	N
Phlox divaricata	Wild blue phlox	1'-2'	Blue	Apr-Jun	P/S	N
Phlox pilosa	Sand prairie phlox	1'-2'	Pink	May-Aug	F/P	N
Physostegia virginiana	Obedient plant	2'-5'	Pink	Aug-Oct	F	Y
Polygonatum biflorum	Solomon seal	1'-4'	Green/ White	May/Jul	P/S	N
Polygonatum pubescens	Downy Solomon seal	1'-3'	White	May-Jul	P/S	N
Pycnanthemum virginianum	Mountain mint	1'-3'	White	Jun-Oct	F/P	N
Ratibida pinnata	Yellow coneflower	3'-6'	Yellow	Jul-Oct	F	N
Rudbeckia hirta	Black-eyed Susan	1'-3'	Yellow	May-Oct	F/P	Y
Rudbeckia triloba	Three-lobed coneflower	2'-5'	Yellow	Aug-Oct	F/P	N
Silphium terebinthinaceum	Prairie-dock	3'-8'	Yellow	Jun-Sep	F	N
Smilacina racemosa	Feathery false Solomon's seal	1'-3'	White	Apr-Jun	P/S	N
Smilacina stellata	Starry false Solomon's seal	1'-2'	White	Apr-Jun	F/P	N
Solidago caesia	Bluestem goldenrod	1'-2'	Yellow	Sep-Oct	P/S	N
Solidago flexicaulis	Zigzag goldenrod	1'-3'	Yellow	Aug/Oct	P/S	N

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Solidago juncea	Early goldenrod	2'-4'	Yellow	Jul-Sep	F/P	N
Solidago speciosa	Showy goldenrod	1'-3'	Yellow	Jul-Oct	F/P	Y
Thalictrum dioicum	Early meadow-rue	1'-3'	Green	Apr-May	P/S	N
Tradescantia ohiensis	Spiderwort	2'-4'	Blue	May-Oct	F/P	N
Vernonia missurica	Missouri ironweed	3'-5'	Purple	Jul-Sep	F	N

Representative Zone E Species

New England Aster

Wild Bergamot

Showy Goldenrod

Tall Bellflower

Wild Geranium

Tall Coreopsis

Redbud

Indian Grass

Source: JFNew

Zone F

Planting Zone = 18 inches or more above water level

These plants tolerate fluctuating water levels within this range, although they are generally less tolerant than most wetter species. They may tolerate short periods of inundation, not to exceed 48 hours in most situations, making them appropriate for upland BMP settings.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Woody Species:						
Acer rubrum	Red maple	90’	Green/red	Mar-May	F/P/S	N
Acer saccharum	Sugar maple	100’	Green	Apr-May	F/P/S	N
Acer saccharinum	Silver Maple	100’	Yellow	Mar-Apr	F/P	N
Betula papyrifera	Paper birch	70’	Brown	Apr-May	F/P	N
Carya ovata	Shagbark hickory	80’	Green	May-Jun	F/P/S	N
Ceanothus americanus	New Jersey tea	1’-3’	White	Jun-Oct	F/P	N
Celtis occidentalis	Hackberry	60’	Green	May	F/P/S	N
Cercis canadensis	Redbud	25’	Red	Apr-May	F/P/S	N
Cornus florida	Flowering dogwood	30’	White	May-Jun	F/P/S	N
Corylus americana	American hazelnut	10’	Yellow	Apr-May	F/P	N
Gymnocladus dioicus	Kentucky coffee tree	85’	White	Jun	F/P	N
Hamamelis virginiana	Witch hazel	30’	Yellow	Oct-Nov	F/P/S	N
Juglans nigra	Black walnut	90’	Green	May	F/P	N
Juniperus virginiana	Red-cedar	50’	Brown	Apr-May	F/P	N
Liriodendron tulipifera	Tulip tree	110’	Green	May-Jun	F/P	N
Morus rubra	Red mulberry	50’	Green	May-Jun	F/P/S	N
Nyssa sylvatica	Black gum	100’	Green	May-Jul	F/P/S	Y
Pinus banksiana	Jack pine	60’	Brown	May-Jun	F/P	N
Pinus resinosa	Red pine	100’	Brown	Apr-May	F/P	N
Pinus strobus	White pine	100’	Brown	Jun	F/P/S	N
Prunus americana	American plum	30’	Red	Apr-May	F/P	N
Prunus virginiana	Choke cherry	30’	White	May-Jun	F/P/S	N
Quercus macrocarpa	Bur oak	85’	Yellow	May-Jun	F/P/S	N
Quercus palustris	Pin oak	90’	Green/yellow	Apr-May	F/P/S	Y
Quercus rubra	Red Oak	90’	Green	May-Jun	F/P/S	N
Rosa carolina	Pasture rose	3’	Pink	Jun-Sep	F/P	N
Tilia americana	Basswood	100’	Yellow	Jun-Jul	F/P/S	N
Tsuga canadensis	Hemlock	100’	Brown	Apr-May	F/P/S	N
Viburnum acerifolium	Maple-leaved Viburnum	7’	White	May-Aug	F/P	N
Viburnum dentatum	Arrowwood	10’	White	May-Jun	F/P/S	N
Grasses/Sedges/Rushes:						
Andropogon gerardii	Big bluestem	4’-8’	Purple	Jul-Sep	F	N
Carex bicknellii	Copper-shouldered oval sedge	1’-2’	Brown	May-Jun	F	N
Carex muhlenbergii	Sand bracted sedge	1’-3’	Brown	May-Jun	F/P/S	N
Elymus canadensis	Canada wild rye	3’-6’	Green	Jun-Sep	F/P	N
Elymus hystrix	Bottlebrush Grass	3’-5’	Green	Jun-Jul	P/S	N
Eragrostis spectabilis	Purple love grass	1’-2’	Purple	Aug-Oct	F	N
Koeleria macrantha	June grass	1’-2’	White	May-Jul	F/P	N
Panicum virgatum	Switch grass	3’-6’	Green/Purple	Jun-Oct	F/P	Y
Schizachyrium scoparium	Little bluestem	2’-4’	Brown	Aug-Sep	F/P	Y
Sorghastrum nutans	Indian Grass	4’-9’	Green	Aug-Sep	F	N
Spartina pectinata	Prairie Cordgrass	6’-7’	Green	Jul-Aug	F	Y

Botanical Name	Common Name	Height	Color	Bloom Time	Sun	Salt Tolerant
Stipa spartea	Porcupine grass	2'-4'	Green	Aug-Sep	F	Y
Forbs:						
Allium cernuum	Nodding wild onion	1'-2'	Lavender	Jun-Oct	F/P	N
Asclepias syriaca	Common milkweed	2'-4'	Pink	Jun-Aug	F/P	N
Asclepias tuberosa	Butterflyweed	1'-3'	Orange	Jun-Sep	F/P	Y
Asclepias verticillata	Whorled milkweed	1'-2'	White	Jun-Sep	F/P	N
Aster cordifolius	Heart-leaved aster	2'-4'	Blue/White	Sep-Oct	P/S	N
Aster laevis	Smooth aster	3'-5'	Blue	Aug-Oct	F	Y
Aster oolentangiensis	Sky-blue aster	1'-4'	Blue	Jul-Nov	F/P	Y
Aster shortii	Short's aster	1'-4'	Blue	Aug-Oct	P/S	N
Cacalia atriplicifolia	Pale Indian plantain	3'-8'	White	Jun-Oct	F/P/S	N
Campanulaa americana	Tall bellflower	2'-6'	Blue	Jul-Nov	P/S	N
Clematis virginiana	Virgin's bower	9' long	White	Jul-Aug	F/P	N
Coreopsis lanceolata	Sand coreopsis	1'-2'	Yellow	May-Aug	F/P	N
Coreopsis palmata	Prairie coreopsis	1'-2'	Yellow	Jun-Aug	F/P	N
Coreopsis tripteris	Tall coreopsis	4'-8'	Yellow	Aug-Sep	F/P	N
Echinacea pallida	Purple coneflower	2'-5'	Lavender	May-Aug	F	N
Eryngium yuccifolium	Rattlesnake master	3'-5'	White	Jul-Sep	F	N
Eupatorium purpureum	Purple Joe-pye weed	3'-6'	Pink	Jul-Sep	P	N
Euphorbia corollata	Flowering spurge	2'-4'	White	May-Oct	F/P	N
Geranium maculatum	Wild geranium	1'-2'	Pink	Apr-Jul	F/P/S	N
Helianthus divaricatus	Woodland sunflower	2'-6'	Yellow	Jun-Sep	P/S	N
Helianthus occidentalis	Western sunflower	2'-4'	Yellow	Aug-Sep	F/P	N
Helianthus pauciflorus	Prairie sunflower	3'-5'	Yellow	Jul-Oct	F	N
Heliopsis helianthoides	False sunflower	4'-6'	Yellow	Jun-Oct	F/P	N
Lespedeza capitata	Round-headed bush clover	2'-4'	Green	Jul-Sep	F/P	N
Liatris aspera	Rough blazing star	2'-3'	Violet	Jul-Nov	F/P	Y
Liatris cylindracea	Cylindrical blazing star	1'-2'	Violet	Jul-Oct	F/P	N
Liatris scariosa	Savanna blazing star	3'-5'	Violet	Aug-Oct	F/P	N
Lupinus perennis	Wild lupine	1'-2'	Purple	Apr-Jun	F/P	N
Monarda fistulosa	Wild bergamot	2'-5'	Lavender	Jul-Sep	F/P	N
Penstemon digitalis	Foxglove beardtongue	2'-4'	White	May-Jul	F/P	N
Phlox pilosa	Sand prairie phlox	1'-2'	Pink	May-Aug	F/P	N
Polygonatum biflorum	Solomon seal	1'-4'	Green/ White	May/Jul	P/S	N
Polygonatum pubescens	Downy Solomon seal	1'-3'	White	May-Jul	P/S	N
Ratibida pinnata	Yellow coneflower	3'-6'	Yellow	Jul-Oct	F	N
Rudbeckia hirta	Black-eyed Susan	1'-3'	Yellow	May-Oct	F/P	Y
Silphium terebinthinaceum	Prairie-dock	3'-8'	Yellow	Jun-Sep	F	N
Smilacina racemosa	Feathery false Solomon's seal	1'-3'	White	Apr-Jun	P/S	N
Smilacina stellata	Starry false Solomon's seal	1'-2'	White	Apr-Jun	F/P	N
Solidago caesia	Bluestem goldenrod	1'-2'	Yellow	Sep-Oct	P/S	N
Solidago juncea	Early goldenrod	2'-4'	Yellow	Jul-Sep	F/P	N
Solidago speciosa	Showy goldenrod	1'-3'	Yellow	Jul-Oct	F/P	Y
Tradescantia ohiensis	Spiderwort	2'-4'	Blue	May-Oct	F/P	N
Veronicastrum virginicum	Culver's root	3'-6'	White	June-Aug	F/P	N

Representative Zone F Species

Spiderwort

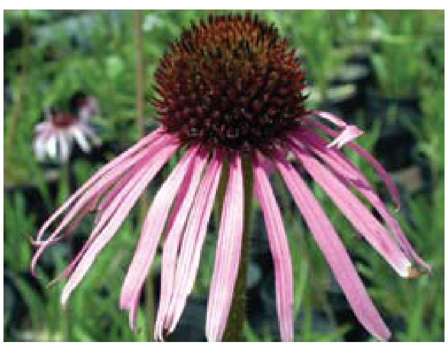
Butterfly Weed

Yellow Coneflower

Little Bluestem

Foxglove Beardtongue

Wild Lupine



Pale Purple Coneflower

Rattlesnake Master

Sand Coreopsis

Source: JFNew

Zone G

Planter Box Plantings

Although this manual typically recommends using native plants wherever possible, certain situations call for nonnative plants due to particular site conditions. Because planter boxes traditionally have a short soil column and are exposed to drier conditions, non-native plants should be considered as long as they are considered non-invasive. Therefore, the list below contains both native and non-native species. Many planter boxes have traditionally used annual flowers. However, we recommend using perennial plants for establishing root systems and lowering maintenance in the long term. Many more species are available for planter boxes than are listed.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun
Ajuga reptans 'Bronze Beauty'	Bronze Beauty Ajuga	6"	Blue	May-Jun	F
Allium maximowiczii 'Alba'	White Flowered Ornamental Chive	6"-1'	White	May-Jun	F
Allium schoenoprasum 'Glaucum'	Blue Flowered Ornamental Chive	6"-1'	Blue	Jun-Jul	F
Allium senescens montanum	Mountain Garlic	6"-1'	Pink/Purple	Jun-Aug	F
Allium senescens glaucum	Curly Onion	6"-1'	Pink	Jul-Sep	F
Allium tanguticum 'Summer Beauty'	Summer Beauty Ornamental Chive	6"-1'	Pink	Jul-Aug	F
Aster 'Wood's Light Blue'	Wood's Light Blue Aster	1'-3'	Blue	Aug-Sep	F
Athryium filix-femina	Lady Fern	1'-3'	Green	NA	F/P/S
Blechnum spicant	Deer Fern	1'-2'	Green	NA	F/P/S
Dryopteris erythrosora	Autumn Fern	1'-2'	Green	NA	F/P/S
Euphorbia myrsinites	Mytle Spurge	6"-1'	Yellow	May-Jun	F
Dryopteris intermedia	Fancy Fern	1'-3'	Green	NA	F/P/S
Dyropteris marginalis	Leatherleaf Fern	1'-2'	Green	NA	F/P/S
Geranium x 'Rozanne'	Rozanne Gernaium	1'-2'	Violet	Jun-Sep	F/P
Hemerocallis 'Barbara Mitchell'	Barbara Mitchell Daylily	2'-3'	Pink	Jun-Aug	F/P
Hemerocallis 'Bill Norris'	Bill Norris Daylily	2'-3'	Yellow	Jun-Aug	F/P
Hemerocallis 'Chicago Apache'	Chicago Apache Daylily	2'-3'	Red	Jul-Sep	F/P
Hosta 'Francee'	Francee Hosta	1'-2'	Lavender	Jul-Aug	F/P/S
Hosta 'Guacamole'	Guacamole Hosta	1'-2'	Pink	Aug-Sep	F/P/S
Hosta 'Summer Fragrance'	Summer Fragrance Hosta	1'-2'	Lavender	Aug-Sep	F/P/S
Hosta sieboldiana 'Elegans'	Elegans Hosta	1'-2'	White	Jul-Aug	F/P/S
Sedum 'Autumn Charm'	Autumn Charm Sedum	6"-1'	Pink	Jun-Jul	F
Sedum 'Joyce Henderson'	Joyce Henderson Sedum	6"-1'	Pink	May-Jun	F
Sedum 'Mini Me'	Mini Me Sedum	6"-1'	Green	NA	F
Sedum acre 'Oktoberfest'	Oktoberfest Sedum	6"-1'	Yellow	Jul-Sep	F
Sedum album 'Athoum'	Jelly Bean Sedum	6"-1'	Pink	Aug-Sep	F
Sedum album 'Coral Carpet'	Coral Carpet Sedum	6"-1'	White	Jun-Aug	F
Sedum album 'Faro Island'	Faro Island Sedum	6"-1'	White	Jun-Aug	F
Sedum album 'Green Ice'	Green Ice Sedum	6"-1'	White	Jun-Jul	F
Sedum album 'Murale'	Wall Sedum	6"-1'	White	Jun-Jul	F
Sedum cauticola 'Sunset Cloud'	Sunset Cloud Sedum	6"-1'	Pink	Jul-Aug	F
Sedum divergens	Cascade Sedum	6"-1'	Yellow	Jun-Jul	F
Sedum ellacombianum	Ellacombe's Sedum	6"-1'	Yellow	May-Jun	F
Sedum ellacombianum 'Variegatum'	Variegated Ellacombe's Sedum	6"-1'	Yelow	May-Jun	F
Sedum floriferum 'Weihenstephaner Gold'	Weihenstephaner Gold Sedum	6"-1'	Yellow	Jun-Jul	F
Sedum grisbachii	Griseback Sedum	6"-1'	Yellow	Jul-Aug	F
Sedum hybridum 'Tekaridake'	Tekaridake Kamtschatka Sedum	6"-1'	Yellow	Jun	F
Sedum kamtschaticum 'Variegatum'	Variegated Kamtschatka Sedum	6"-1'	Orange	Jul-Aug	F
Sedum middendorfianum var. diffusum	Diffuse Middendorf's Sedum	6"-1'	Yellow	May-Jun	F

Representative Zone G Species

Guacamole Hosta

Mountain Garlic

Wall Sedum

Lady Fern

Source: JFNew

Zone H

Vegetated Roof Plantings

Research to-date shows that native plants do not typically thrive in vegetated roofs. Therefore, the list below reflects species that are known to thrive in green roof situations. All species listed below will generally grow to a height of 6-to-18 inches.

Botanical Name	Common Name	Height	Color	Bloom Time	Sun
Ajuga reptans 'Bronze Beauty'	Bronze Beauty Ajuga	6"	Blue	May-Jun	F
Allium maximowiczii 'Alba'	White Flowered Ornamental Chive	6"-1'	White	May-Jun	F
Allium schoenoprasum 'Glaucum'	Blue Flowered Ornamental Chive	6"-1'	Blue	Jun-Jul	F
Allium senescens montanum	Mountain Garlic	6"-1'	Pink/Purple	Jun-Aug	F
Allium senescens glaucum	Curly Onion	6"-1'	Pink	Jul-Sep	F
Allium tanguticum 'Summer Beauty'	Summer Beauty Ornamental Chive	6"-1'	Pink	Jul-Aug	F
Aster 'Wood's Light Blue'	Wood's Light Blue Aster	1'-3'	Blue	Aug-Sep	F
Athryium filix-femina	Lady Fern	1'-3'	Green	NA	F/P/S
Blechnum spicant	Deer Fern	1'-2'	Green	NA	F/P/S
Dryopteris erythrosora	Autumn Fern	1'-2'	Green	NA	F/P/S
Euphorbia myrsinites	Mytle Spurge	6"-1'	Yellow	May-Jun	F
Dryopteris intermedia	Fancy Fern	1'-3'	Green	NA	F/P/S
Dyropteris marginalis	Leatherleaf Fern	1'-2'	Green	NA	F/P/S
Geranium x 'Rozanne'	Rozanne Gernaium	1'-2'	Violet	Jun-Sep	F/P
Hemerocallis 'Barbara Mitchell'	Barbara Mitchell Daylily	2'-3'	Pink	Jun-Aug	F/P
Hemerocallis 'Bill Norris'	Bill Norris Daylily	2'-3'	Yellow	Jun-Aug	F/P
Hemerocallis 'Chicago Apache'	Chicago Apache Daylily	2'-3'	Red	Jul-Sep	F/P
Hosta 'Francee'	Francee Hosta	1'-2'	Lavender	Jul-Aug	F/P/S
Hosta 'Guacamole'	Guacamole Hosta	1'-2'	Pink	Aug-Sep	F/P/S
Hosta 'Summer Fragrance'	Summer Fragrance Hosta	1'-2'	Lavender	Aug-Sep	F/P/S
Hosta sieboldiana 'Elegans'	Elegans Hosta	1'-2'	White	Jul-Aug	F/P/S
Sedum 'Autumn Charm'	Autumn Charm Sedum	6"-1'	Pink	Jun-Jul	F
Sedum 'Joyce Henderson'	Joyce Henderson Sedum	6"-1'	Pink	May-Jun	F
Sedum 'Mini Me'	Mini Me Sedum	6"-1'	Green	NA	F
Sedum acre 'Oktoberfest'	Oktoberfest Sedum	6"-1'	Yellow	Jul-Sep	F
Sedum album 'Athoum'	Jelly Bean Sedum	6"-1'	Pink	Aug-Sep	F
Sedum album 'Coral Carpet'	Coral Carpet Sedum	6"-1'	White	Jun-Aug	F
Sedum album 'Faro Island'	Faro Island Sedum	6"-1'	White	Jun-Aug	F
Sedum album 'Green Ice'	Green Ice Sedum	6"-1'	White	Jun-Jul	F
Sedum album 'Murale'	Wall Sedum	6"-1'	White	Jun-Jul	F
Sedum cauticola 'Sunset Cloud'	Sunset Cloud Sedum	6"-1'	Pink	Jul-Aug	F
Sedum divergens	Cascade Sedum	6"-1'	Yellow	Jun-Jul	F
Sedum ellacombianum	Ellacombe's Sedum	6"-1'	Yellow	May-Jun	F
Sedum ellacombianum 'Variegatum'	Variegated Ellacombe's Sedum	6"-1'	Yelow	May-Jun	F
Sedum floriferum 'Weihenstephaner Gold'	Weihenstephaner Gold Sedum	6"-1'	Yellow	Jun-Jul	F
Sedum grisbachii	Griseback Sedum	6"-1'	Yellow	Jul-Aug	F
Sedum hybridum 'Tekaridake'	Tekaridake Kamtschatka Sedum	6"-1'	Yellow	Jun	F
Sedum kamtschaticum 'Variegatum'	Variegated Kamtschatka Sedum	6"-1'	Orange	Jul-Aug	F
Sedum middendorfianum var. diffusum	Diffuse Middendorf's Sedum	6"-1'	Yellow	May-Jun	F

Representative Zone H Species

Mountain Garlic

Cascade Sedum

Wall Sedum

Ellacombe's Sedum

Source: JFNew

Credits and Acknowledgments

This Appendix has been developed by Christopher B. Burke Engineering, LLC, and is primarily based upon similar segments contained in "Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers" published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this Appendix. The valuable contribution of SEMCOG through sharing of this material for use in this Appendix is hereby acknowledged.

Recommended Materials

Appendix D3

Recommended Materials

Numerous BMPs in this manual have similar material needs. These BMPs are listed in the table below. Detailed information on each material requirement follows. In addition, Porous Pavement and Vegetated Roofs have significant material requirements that are listed according to their individual needs.

	Constructed Filters	Dry Well	Infiltration Trench	Planter Boxes	Porous Pavement	Subsurface Infiltration	Vegetated Filter Strip	Vegetated Swale
Check dams							X	X
Non-Woven Geotextile	X	X	X	X	X	X	X	
Pea Gravel							X	
Peat	X			X				
Pervious Berms							X	
Pipe – 8”	X	X	X	X	X	X	X	
Sand	X			X				X
Stone/Gravel	X			X				
Stone – 30%							X	
Stone – 40%			X		X			

Check dams (Vegetated Filter Strip, Vegetated Swale)

An earthen check dam shall be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02 in to 0.04 in, Gravel: AASHTO M-43 0.5 in to 1.0 in). A stone check dam shall be constructed of R-4 rip rap, or equivalent.

Non-Woven Geotextile (Constructed Filter, Dry Well, Infiltration Trench, Planter Boxes, Vegetated Filter Strip)

Should consist of needled nonwoven polypropylene fibers and meet the following properties:

a.	Grab Tensile Strength (ASTM-D4632)	120 lbs minimum
b.	Mullen Burst Strength (ASTM-D3786)	225 psi minimum
c.	Flow Rate (ASTM-D4491)	110 gal/min/ft^2 minimum
d.	UV Resistance after 500 hrs (ASTM-D4355)	70% minimum
e.	Puncture strength (ASTM D-4833-00)	90 lbs minimum
f.	Apparent opening size (ASTM D-4751-99A)	60-70 US Sieve

Heat-set or heat-calendared fabrics are not permitted. Acceptable types include Mirafi 140N, Amoco 4547, Geotex 451, or approved others.

Pea Gravel (Vegetated Filter Strip)

Clean bank-run gravel may also be used and should meet ASTM D 448 and be sized as per No.6 or 1/8” to 3/8”.

Peat (Constructed Filter, Planter Boxes)

Should have ash content <15%, pH range 3.3-5.2, loose bulk density range 0.12-0.14 g/cc.

Pervious Berms (Vegetated Filter Strip)

The berm shall have a height of 6-12 inches and be constructed of sand, gravel, and sandy loam to encourage grass cover. (Sand: ASTM C-33 fine aggregate concrete sand 0.02”-0.04”, Gravel: AASHTO M-43, ½” to 1”)

Pipe - (Dry Well, Porous Pavement, Subsurface Infiltration, Constructed Filter, Infiltration Trench, Planter Boxes, Vegetated Filter Strip)

Should be continuously perforated, double-wall, smooth interior (smooth bore), with a minimum inside diameter as required. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or M294, Type S (12-gauge aluminum or pipe may also be used in seepage pits).

Sand (Constructed Filter, Planter Boxes, Vegetated Swale)

Should be ASTM-C-33 (or AASHTO M-6) size (0.02” – 0.04”), concrete sand, clean, medium to fine sand.

Soil Testing (all BMPs)

Should be completed in accordance to the Purdue University Cooperative Extension Service Department of Horticulture “Collecting Soil Samples for Testing” HO-71-W” http://www.hort.purdue.edu/ext/HO-71.pdf

Stone/Gravel (Constructed Filter, Planter Boxes):

Should be uniformly graded coarse aggregate, 1-inch to ½-inch with a wash loss of no more than 0.5%, AASHTO size number 5 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and have voids of 40% as measured by ASTM-C29.

Stone – 40% voids (Infiltration Trench, Porous Pavement, Subsurface Infiltration Bed,)

Infiltration trenches should have stone 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

Porous Pavement

General

Choker base course aggregate for beds shall be 3/8 inch to 3/4 inch clean, uniformly-graded, coarse, crushed aggregate AASHTO size number 57 per Table 4, AASHTO Specifications, Part I, 19th Ed., 1998 (p. 47).

Porous Asphalt

Bituminous surface course for porous paving shall be 2.5 to 3 inches thick with a bituminous mix of 5.75% to 6.75% by total weight as determined by testing below. Use neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 76-22P as specified in AASHTO MP-1. The composite materials shall be thoroughly blended at the asphalt refinery or terminal prior to being loaded into the transport vehicle. The polymer modified asphalt binder shall be heat and storage stable.

Determination of optimal asphalt content should be determined according the following tests:

- Draindown Test (ASTM Method D6390)
- Moisture Susceptibility Test using the Modifed Lottman Method (AASHTO T283) with the following:
    - Compact using 50 gyrations of Superpave gyratory compactor
    - Apply partial vacuum of 26 inches of Hg for 10 minutes to whatever saturation is achieved.
    - Keep specimens submerged in water during freeze cycle.
    - Required retained tensile strength (TSR) $\geq$ 80%

- Air Voids Test (AASHTO T269/ASTM D3203)

Hydrated lime, if required, shall meet the requirements of AASHTO M 303 Type 1 and shall be blended with the damp aggregate at a rate of 1.0% by weight of the total dry aggregate. The additive must be able to prevent the separation of the asphalt binder from the aggregate and achieve a required tensile strength ratio (TSR) of at least 80% on the asphalt mix.

Fibers, if used, shall consist of either cellulose fibers or mineral fibers which are to be treated with a cationic sizing agent to enhance dispersement of the fiber as well as increase cohesion of the fiber to the bitumen. Fiber is to be added at a dosage rate between 0.2% and 0.4% by weight of total mix.

- Mineral fibers shall be from virgin, basalt, diabase, or slag with a maximum average fiber length of 6.35 mm and a maximum average fiber thickness of 0.005 mm.
- Cellulose fiber – Fiber length shall be 6.4 mm (max), Ash Content 18% non-volatiles (±5%), pH 7.5 (± 1), Oil absorption (times fiber weight) 5.0 (± 1), Moisture Content 5.0 (max).

Porous Concrete

The use of Installers or Craftsmen who have been certified by the NRMCA's Pervious Concrete Contractor Certification Program is strongly recommended. Contractor shall furnish a proposed mix design with all applicable information to the Engineer prior to commencement of work. Critical mix characteristics typically include the following:

- Cement Content: 550 to 650 lb/yd^3
- Fine aggregate, if used: maximum 3 cubic feet per cubic yard
- Admixtures: use in accordance with the manufacturer's instructions and recommendations
- An aggregate/cement (A/C) ratio: 4:1 to 4.5:1
- Water/cement (W/C) ratio: 0.27 to 0.34
- Curing: shall begin within 15 minutes after placement and continue for 7 days

The data shall include unit weights determined in accordance with ASTM C29 paragraph 11, jigging procedure.

Cement: Portland Cement Type II or V conforming to ASTM C150 or Portland Cement Type IP or IS conforming to ASTM C595. The total cementitious material shall be between 550 and 650 lb/yd^3.

Aggregate: Use No 8 coarse aggregate (3/8 to No. 16) per ASTM C33 or No. 89 coarse aggregate (3/8 to No. 50) per ASTM D 448. If other gradation of aggregate is to be used, submit data on proposed material to owner for approval. The volume of aggregate per cubic yard shall be equal to 27 cubic feet when calculated as a function of the unit weight determined in accordance with ASTM C29 jigging procedure. Fine aggregate, if used, should not exceed 3 cubic feet and shall be included in the total aggregate volume.

Air Entraining Agent: Shall comply with ASTM C 260 and shall be used to improve workability and resistance to freeze/thaw cycles.

Admixtures: The following admixtures shall be used:

- Type D Water Reducing/Retarding – ASTM C 494.
- A hydration stabilizer that also meets the requirements of ASTM C 494 Type B Retarding or Type D Water Reducing/Retarding admixtures may be used. This stabilizer suspends cement hydration by forming a protective barrier around the cementitious particles, which delays the particles from achieving initial set.

Water: Potable shall be used and shall comply with ASTM C1602. Mix water shall be such that the cement paste displays a wet metallic sheen without causing the paste to flow from the aggregate. (Mix water yielding a cement paste with a dull-dry appearance has insufficient water for hydration).

- Insufficient water results in inconsistency in the mix and poor bond strength.
- High water content results in the paste sealing the void system primarily at the bottom and poor surface bond.

An aggregate/cement (A/C) ratio range of 4:1 to 4.5:1 and a water/cement (W/C) ratio range of 0.27 to 0.34 should produce pervious pavement of satisfactory properties in regard to permeability, load carrying capacity, and durability characteristics.

Vegetated roofs

Some key components and associated performance-related properties are as follows:

Root-barriers should be thermoplastic membranes with a thickness of at least 30 mils. Thermoplastic sheets can be bonded using hot-air fusion methods, rendering the seams safe from root penetration. Membranes that have been certified for use as root-barriers are recommended. At present only FLL offers a recognized test for root-barriers. Several FLL-certified materials are available in the United States. Interested American manufactures can submit products for testing to FLL-certified labs.

Granular drainage media should be a non-carbonate mineral aggregate conforming to the following specifications:

- Saturated Hydraulic Conductivity ≥ 25 in/min
- Total Organic Matter, by Wet Combustion (MSA) ≤ 1%
- Abrasion Resistance (ASTM-C131-96) ≤ 25% loss
- Soundness (ASTM-C88 or T103 or T103-91) ≤ 5% loss
- Porosity (ASTM-C29) ≥ 25%
- Alkalinity, $CaCO_3$ equivalents (MSA) ≤ 1%
- Grain-Size Distribution (ASTM-C136)
  - Percentage Passing US#18 sieve ≤ 1%
  - Percentage Passing ¼-inch sieve ≤ 30%
  - Percentage Passing 3/8-inch sieve ≤ 80%

Growth media should be a soil-like mixture containing not more than 15% organic content (wet combustion or loss on ignition methods). The appropriate grain-size distribution is essential for achieving the proper moisture content, permeability, nutrient management, and non-capillary porosity, and 'soil' structure. The grain-size guidelines vary

- Non-capillary Pore Space at Field Capacity, 0.333 bar (TMECC 03.01, A) ≥ 15% (vol)
- Moisture Content at Field Capacity (TMECC 03.01, A) ≥ 12% (vol)
- Maximum Media Water Retention (FLL) ≥ 30% (vol)
- Alkalinity, Ca CO3 equivalents (MSA) ≤ 2.5%
- Total Organic Matter by Wet Combustion (MSA) 3-15% (dry wt.)
- pH (RCSTP) 6.5 - 8.0
- Soluble Salts (DTPA saturated media extraction)"(RCSTP) ≤ 6 mmhos/cm
- Cation exchange capacity (MSA) ≥ 10 meq/100g

- Saturated Hydraulic Conductivity for Single Media Assemblies (FLL) ≥ 0.05 in/min
- Saturated Hydraulic Conductivity for Dual Media Assemblies (FLL) ≥ 0.30 in/min

Grain-size Distribution of the Mineral Fraction (ASTM-D422)

- Single Media Assemblies:
  - Clay fraction (2 micron) 0
  - Pct. Passing US#200 sieve (i.e., silt fraction) ≤ 5%
  - Pct. Passing US#60 sieve ≤ 10%
  - Pct. Passing US#18 sieve 5 - 50%
  - Pct. Passing 1/8-inch sieve 0 - 70%
  - Pct. Passing 3/8-inch sieve 75 -100%

- Dual Media Assemblies:
  - Clay fraction (2 micron) 0
  - Pct. Passing US#200 sieve (i.e., silt fraction) 5 - 15%
  - Pct. Passing US#60 sieve 10 - 25%
  - Pct. Passing US#18 sieve 20 - 50%
  - Pct. Passing 1/8-inch sieve 55 - 95%
  - Pct. Passing 3/8-inch sieve 90 - 100%

Macro- and micro-nutrients shall be incorporated in the formulation in initial proportions suitable for support the specified planting.

Separation fabric should be readily penetrated by roots, but provide a durable separation between the drainage and growth media layers (Only lightweight nonwoven geotextiles are recommended for this function.

- Unit Weight (ASTM-D3776) ≤ 4.25 oz/yd^2
- Grab tensile (ASTM-D4632) ≤ 90 lb
- Mullen Burst Strength (ASTM-D4632) ≥ 135 lb/in
- Permittivity (ASTM-D4491) ≥ 2 per second

Credits and Acknowledgments

This Appendix has been developed by Christopher B. Burke Engineering, LLC, and is primarily based upon similar segments contained in “Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers” published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this Appendix. The valuable contribution of SEMCOG through sharing of this material for use in this Appendix is hereby acknowledged.

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Soil Infiltration Testing Protocol

Appendix D4

Soil Infiltration Testing Protocol

Purpose of this Protocol

The soil infiltration testing protocol describes evaluation and field testing procedures to determine if infiltration BMPs are suitable at a site, as well as to obtain the required data for infiltration BMP design.

When to Conduct Testing

It is recommended that soil evaluation and investigation be conducted following development of a concept plan or early in the development of a preliminary plan.

Who Should Conduct Testing

Soil evaluation and investigation may be conducted by soil scientists, design engineers, professional geologists, and other qualified professionals and technicians. The stormwater designer is *strongly* encouraged to directly observe the testing process to obtain a first-hand understanding of site conditions.

Importance of Stormwater BMP Areas

Sites are often defined as unsuitable for infiltration BMPs and soil-based BMPs due to proposed grade changes (excessive cut or fill) or lack of suitable areas. Many sites will be constrained and unsuitable for infiltration BMPs. However, if suitable areas exist, these areas should be identified early in the design process and should not be subject to a building program that precludes infiltration BMPs. When pursuing the LID Approach, full build-out of site areas otherwise deemed to be suitable for infiltration should not provide an exemption or waiver for adequate storm-water volume control or groundwater recharge.

Safety

As with all field work and testing, attention to all applicable Occupational Safety and Health Administration (OSHA) regulations and local guidelines related to earthwork and excavation is required. Digging and excavation should never be conducted without adequate notification through the. Indiana Underground Plant Protection Service (IUPPS) at www.IUPSS.org. Excavations should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work.

Infiltration Testing: A Multi-Step Process

Infiltration testing is a four-step process to obtain the necessary data for the design of the stormwater management plan. The four steps include:

1. **Background evaluation**
   - Based on available published and site specific data
   - Includes consideration of proposed development plan
   - Used to identify potential BMP locations and testing locations
   - Prior to field work (desktop)
2. **Test pit (deep hole) observations**
   - Includes multiple testing locations
   - Provides an understanding of sub-surface conditions
   - Identifies limiting conditions
3. **Infiltration testing**
   - Must be conducted onsite
   - Different testing methods available
4. **Design considerations**
   - Determine suitable infiltration rate for design calculations
   - Consider BMP drawdown
   - Consider peak rate attenuation

Step 1. Background evaluation

Prior to performing testing and developing a detailed site plan, existing conditions at the site should be inventoried and mapped including, but not limited to:

- Existing mapped soils and USDA Hydrologic Soil Group classifications.
- Existing geology, including depth to bedrock, karst conditions, or other features of note.
- Existing streams (perennial and intermittent, including intermittent swales), water bodies, wetlands, hydric soils, floodplains, alluvial soils, stream classifications, headwaters, and first order streams.
- Existing topography, slope, drainage patterns, and watershed boundaries.
- Existing land use conditions.

- Other natural or man-made features or conditions that may impact design, such as past uses of site, existing nearby structures (buildings, walls), abandoned wells, etc.

- A concept plan or preliminary layout plan for development should be evaluated, including:
  - Preliminary grading plan and areas of cut and fill,
  - Location of all existing and proposed water supply sources and wells,
  - Location of all former, existing, and proposed onsite wastewater systems,
  - Location of other features of note such as utility rights-of-way, water and sewer lines, etc.,
  - Existing data such as structural borings, and
  - Proposed location of development features (buildings, roads, utilities, walls, etc.).

In Step 1, the designer should determine the potential location of infiltration BMPs. The approximate location of these BMPs should be on the proposed development plan and serve as the basis for the location and number of tests to be performed onsite.

Important: If the proposed development is located on areas that may otherwise be a suitable BMP location, or if the proposed grading plan is such that potential BMP locations are eliminated, the designer is *strongly* encouraged to revisit the proposed layout and grading plan and adjust the development plan as necessary. Full build-out of areas suitable for infiltration BMPs should *not* preclude the use of BMPs for runoff volume reduction and groundwater recharge.

Step 2. Test pits (deep holes)

A test pit (deep hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. An extensive number of test pit observations can be made across a site at a relatively low cost and in a short time period. The use of soil borings as a substitute for test pits is strongly discouraged, as visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings.

A test pit (deep hole) consists of a backhoe-excavated trench, 2½-3 feet wide, to a depth of 6-7½ feet, or until bedrock or fully saturated conditions are encountered. The trench should be benched at a depth of 2-3 feet for access and/or infiltration testing.

At each test pit, the following conditions are to be noted and described. Depth measurements should be described as depth below the ground surface:

- Soil horizons (upper and lower boundary),
- Soil texture, structure, and color for each horizon,
- Color patterns (mottling) and observed depth,
- Depth to water table,
- Depth to bedrock,
- Observance of pores or roots (size, depth),
- Estimated type and percent coarse fragments,
- Hardpan or limiting layers,
- Strike and dip of horizons (especially lateral direction of flow at limiting layers), and
- Additional comments or observations.

The Sample Soil Log Form at the end of this protocol may be used for documenting each test pit.

At the designer's discretion, soil samples may be collected at various horizons for additional analysis. Following testing, the test pits should be refilled with the original soil and the topsoil replaced. A test pit should *never* be accessed if soil conditions are unsuitable or unstable for safe entry, or if site constraints preclude entry. OSHA regulations should always be observed.

It is important that the test pit provide information related to conditions at the bottom of the proposed infiltration BMP. If the BMP depth will be greater than 90 inches below existing grade, deeper excavation of the test pit will be required. The designer is cautioned regarding the proposal of systems that are significantly deeper than the existing topography, as the suitability for infiltration is likely to decrease. The design engineer is encouraged to consider reducing grading and earthwork as needed to reduce site disturbance and provide greater opportunity for stormwater management.

The number of test pits varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For single-family residential subdivisions with on-lot infiltration BMPs, one test pit per lot is recommended, preferably within 100 feet of the proposed BMP area.

- For multi-family and high-density residential developments, one test pit per BMP area or acre is recommended.
- For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four to six pits per acre of BMP area.

The recommendations above are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table levels, depth and type of bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the site prior to construction is not recommended.

Step 3. Infiltration tests

A variety of field tests exists for determining the infiltration capacity of a soil. Laboratory tests are not recommended, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Infiltration tests should not be conducted in the rain, within 24 hours of significant rainfall events (> 0.5 inches), or when the temperature is below freezing.

At least one test should be conducted at the proposed bottom elevation of an infiltration BMP, and a minimum of two tests per test pit are recommended. Based on observed field conditions, the designer may elect to modify the proposed bottom elevation of a BMP. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions.

Methodologies discussed in this protocol include:

- Double-ring infiltrometer tests.
- Percolation tests (such as for onsite wastewater systems).

There are differences between the two methods. A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil from the inner ring. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in a percolation test must be adjusted to represent the discharge that is occurring on both the bottom and sides of the percolation test hole.

Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head double-ring infiltrometer.
- Testing as described in the *Maryland Stormwater Manual*, Appendix D.1, using five-inch diameter casing.
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D 3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer.
- ASTM 2002 Volume 4.09, Soil and Rock (II): Designation D 5093-90, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.
- Guelph permeameter.
- Constant head permeameter (Amoozemeter).

Methodology for double-ring infiltrometer field test

A double-ring infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop-in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is the amount of water per surface area and time unit which penetrates the soils. The diameter of the inner ring should be approximately 50-70 percent of the diameter of the outer ring, with a minimum inner ring size of four inches. Double-ring infiltrometer testing equipment designed specifically for that purpose may be purchased. However, field testing for storm-water BMP design may also be conducted with readily available materials.

<u>Equipment for double-ring infiltrometer test:</u>
Two concentric cylinder rings six inches or greater in height. Inner ring diameter equal to 50-70 percent of outer ring diameter (i.e., an 8-inch ring and a 12-inch ring). Material typically available at a hardware store may be acceptable.

- Water supply,
- Stopwatch or timer,
- Ruler or metal measuring tape,
- Flat wooden board for driving cylinders uniformly into soil,

- Rubber mallet, and
- Log sheets for recording data.

Procedure for double-ring infiltrometer test

- Prepare level testing area.
- Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of two inches.
- Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of two inches. The bottom rim of both rings should be at the same level.
- The test area should be presoaked immediately prior to testing. Fill both rings with water to water level indicator mark or rim at 30-minute intervals for one hour. The minimum water depth should be four inches. The drop in the water level during the last 30 minutes of the presoaking period should be applied to the following standard to determine the time interval between readings:

    - If water level drop is two inches or more, use 10-minute measurement intervals.
    - If water level drop is less than two inches, use 30-minute measurement intervals.

- Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring should be made from a fixed reference point and should continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼-inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the center ring during the final period or the average stabilized rate, expressed as inches per hour, should represent the infiltration rate for that test location.

Methodology for percolation test

Equipment for percolation test

- Post hole digger or auger,
- Water supply,
- Stopwatch or timer,
- Ruler or metal measuring tape,
- Log sheets for recording data,
- Knife blade or sharp-pointed instrument (for soil scarification),
- Course sand or fine gravel, and
- Object for fixed-reference point during measurement (nail, toothpick, etc.).

Procedure for percolation test

This percolation test methodology is based largely on the criteria for onsite sewage investigation of soils. A 24-hour pre-soak is generally not required as infiltration systems, unlike wastewater systems, will not be continuously saturated.

- Prepare level testing area.
- Prepare hole having a uniform diameter of 6-10 inches and a depth of 8-12 inches. The bottom and sides of the hole should be scarified with a knife blade or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material should be removed from the hole.
- (Optional) Two inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.
- Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of six inches over the bottom and readjusted every 30 minutes for one hour.
- The drop in the water level during the last 30 minutes of the final presoaking period should be applied to the following standard to determine the time interval between readings for each percolation hole:
    - If water remains in the hole, the interval for readings during the percolation test should be 30 minutes.
    - If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.
- After the final presoaking period, water in the hole should again be adjusted to a minimum depth of six inches and readjusted when necessary after each reading. A nail or marker should be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter should be recorded.
- Measurement to the water level in the individual percolation holes should be made from a fixed reference point and should continue at the interval determined from the previous step for each

individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼ inch or less of drop between the highest and lowest readings of four consecutive readings.

- The drop that occurs in the percolation hole during the final period, expressed as inches per hour, should represent the percolation rate for that test location.
- The average measured rate must be adjusted to account for the discharge of water from both the sides and bottom of the hole and to develop a representative infiltration rate. The average/final percolation rate should be adjusted for each percolation test according to the following formula:

Infiltration Rate = (Percolation Rate)/ (Reduction Factor)

Where the Reduction Factor is given by[#]:

$$R_f = \frac{2d_i - \Delta d}{DIA} + 1$$

With:

d_i = Initial Water Depth (in.)
$\triangle$d = Average/Final Water Level Drop (in.)
DIA = Diameter of the Percolation Hole (in.)

The percolation rate is simply divided by the reduction factor as calculated above or shown in Table 1 below to yield the representative infiltration rate. In most cases, the reduction factor varies from about two to four depending on the percolation hole dimensions and water level drop – wider and shallower tests have lower reduction factors because proportionately less water exfiltrates through the sides.

 # The area reduction factor accounts for the exfiltration occurring through the sides of percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the percolating surface of the hole is in uniform soil. If there are significant problems with either of these assumptions then other adjustments may be necessary.

Step 4. Use design considerations provided in the infiltration BMP.

Perc. Hole Diameter, DIA (in.)	Initial Water Depth, d_i (in.)	Ave./Final Water Level Drop, Δd (in.)	Reduction Factor, R_f
6	6	0.1	3.0
		0.5	2.9
		2.5	2.6
	8	0.1	3.7
		0.5	3.6
		2.5	3.3
	10	0.1	4.3
		0.5	4.3
		2.5	3.9
8	6	0.1	2.5
		0.5	2.4
		2.5	2.2
	8	0.1	3.0
		0.5	2.9
		2.5	2.7
	10	0.1	3.5
		0.5	3.4
		2.5	3.2
10	6	0.1	2.2
		0.5	2.2
		2.5	2.0
	8	0.1	2.6
		0.5	2.6
		2.5	2.4
	10	0.1	3.0
		0.5	3.0
		2.5	2.8

Table 1 Sample Percolation Rate Adjustments

Additional Potential Testing – Bulk Density

Bulk density tests measure the level of compaction of a soil, which is an indicator of a soil's ability to absorb rainfall. Developed and urbanized sites often have very high bulk densities and, therefore, possess limited ability to absorb rainfall (and have high rates of stormwater runoff). Vegetative and soil improvement programs can lower the soil bulk density and improve the site's ability to absorb rainfall and reduce runoff.

Macropores occur primarily in the upper soil horizons and are formed by plant roots (both living and decaying), soil fauna such as insects, the weathering processes caused by movement of water, the freeze-thaw cycle, soil shrinkage due to desiccation of clays, chemical processes, and other mechanisms. These macropores provide an important mechanism for infiltration prior to development, extending vertically and horizontally for considerable distances. It is the intent of good engineering and design practice to maintain these macropores when installing infiltration BMPs as much as possible. Bulk density tests can help determine the relative compaction of soils before and after site disturbance and/or restoration and should be used at the discretion of the designer/reviewer.

Soil Test Pit Log Sheet

Project: ____________________________________ Date: ______________________________
Name:______________________________________ Soil Series: ________________________
Location: ___________________________________ Other: ______________________________
Test Pit #: __________________________________

Horizon	Depth (in.)	Color	Redox Features	Texture	Notes (if applicable)	Boundary

Notes:

REDOX FEATURES
Abundance
Few……..< 2%
Common..2-20%
Many…….>20%
Contrast
faint
hue and chroma of matrix and redox are closely related
distinct
matrix & redox features vary 1-2 units of hue and several units of chroma & value
prominent
Matrix & redox features vary several units in hue, value & chroma

COARSE FRAGMENTS (% of profile)

15-35%	35-65%	>65%
gravelly	very gravelly	extremely gravelly
channery	very channery	extremely channery
cobbly	very cobbly	extremely cobbly
flaggy	very flaggy	extremely flaggy
stony	very stony	extremely stony

BOUNDARY
Distinctness
abrupt… < 1" (thick) *gradual…2.5" – 5"*
clear…. 1" – 2.5" *diffuse… > 5"*

HORIZONS
O – organic layers of decaying plant and animal tissue (must be greater than 12-18% organic carbon, excluding live roots)
A (topsoil) – mineral horizon at or near the surface in which an accumulation of humified organic matter is mixed with the mineral material
E – mineral horizon which the main feature is loss of silicate clay, iron, aluminum. Must be underlain by B (alluvial) horizon.
B (subsoil) – mineral horizon with evidence of pedogenesis or illuviation (movement into the horizon)
C (substratum) – the un-weathered geologic material the soil formed in. Shows little or no sign of soil formation

Credits and Acknowledgments

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Maintenance Inspection Checklists

Appendix D5

MAINTENANCE INSPECTION CHECKLISTS

This appendix contains four checklists available as guides for maintenance inspections of specific BMPs. The maintenance items have been adapted from multiple stormwater programs, including the Rouge River Detention Basin Maintenance Manual, Georgia Stormwater Management Manual, the Vermont Stormwater Management Manual, and the Stormwater Manager's Resource Center.

The checklists are designed to help identify key components of BMPs that require ongoing maintenance as well as a basic schedule of when the maintenance should occur. The checklists have been divided into those items essential for the general operation and functionality of the BMP and those items that optional and may enhance the BMP.

It is suggested that the inspection be undertaken by a licensed PE and/or a person knowledgeable about the design and function of the BMP.

These BMP checklists include:

- Detention (ponds, basins, wetlands)
- Infiltration (basins, trenches)
- Bioretention
- Bioswales, vegetated filter strips

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Detention BMP Inspection Checklist*

Project Location:____

Date/Time: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Inlet/Outlet Pipes			
Structural integrity of inlet/outlet (Are any inlet pipes broken, crumbling, separated?) List Approximate Diameter and Type of Material of Inlet Pypes Inlet Pipe 1________________________ Inlet Pipe 2________________________ Inlet Pipe 3________________________ Outlet Pipe Size/Type________________		A	
Riprap at inlet pipe (Is the riprap still present? Is it visible and not covered with sediment?		A	
Stone around outlet pipe (Is the stone clogged with debris and/or sediment?)		A	
Trash or debris blocking inlet/outlet (Inspect to ensure no major obstructions hindering general functionality)		M	
Inspect/clean catch basin upstream of the BMP if accessible.		A	
Inspect inlets and outlet for erosion (Are there eroded areas around the pipes?)		A	
Inspect overflow spillway for signs of erosion.			
Pretreatment (if applicable). This might include sediment forebay, upstream catch basin, bioswale, rain garden, swirl concentrator			
Device functioning to trap/collect sediment			
Remove accumulated sediment as appropriate for the pretreatment device. forebay		A	
Detention Pond		A	

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* It is recommended to review and inspect the basin with the engineering as-built plans.

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Inspect side slopes, berms and emergency overflow for erosion		A	
Reestablish permanent native vegetation on eroded slopes		As Needed	
Inspect for excess sediment accumulation in pond if not pretreatment device is present		A	
Overall functionality			
Ensure pond is functioning properly (Professional Civil Engineer is recommended)		A	
Ensure the outlet is functioning properly (Professional Civil Engineer is recommended)		A	
Optional/Enhancements			
Maintain 15-20 feet “no mow and chemical free” zone		A	
Mow (or burn) the “no mow” zone		A	
Inspect basin and “no mow” zone for invasive species.		A	
Qualified professional applicator selectively herbicide invasive species		A	
Increase plant diversity by planting additional vegetation in and around pond.		A	
Complaints from residents (note on back)		S	
Encroachment on pond/no- mow zone.		A	
Unauthorized plantings		A	
Aesthetics (e.g., graffiti, unkempt maintenance)		A	

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* It is recommended to review and inspect the basin with the engineering as-built plans.

Summary

Inspector’s remarks:

____

____

Overall condition of facility (acceptable or unacceptable): ____________________________________

Dates any maintenance must be completed by: ____

Infiltration BMPs Inspection Checklist*

Project Location: ____

Date/Time: ____

Inspector: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Inlet/Outlet			
Structural integrity of inlet/outlet		A	
Inlet/outlet clear of debris		M	
Overflow spillway clear of debris		M	
Erosion control at inlet in place (e.g., rock, mat)/ evidence of erosion		A	
Erosion control at outlet in place/evidence of erosion		A	
Inspect/clean catch basin upstream of BMP		A	
Pretreatment for Sediment			
Device functioning to trap sediment		A	
Remove accumulated sediment		A	
Overall functionality			
Ensure infiltration device is functioning properly (professional civil engineer is recommended)		A	
BMP infiltration surface			
Evidence of sedimentation in BMP		A	
Does sediment accumulation currently require removal		A	
Debris in BMP		S	
Evidence of erosion present		A	
Aggregate (if applicable)			
Surface of aggregate clean		A	
Any replacement of aggregate needed? If clogged with sediment, replacement is necessary for continued proper function.		A	

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* Prior to field inspection, it is recommended to review the as-built plans.

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Vegetated surface (if applicable)			
Vegetative cover exists		A	
Optional considerations			
Inspect BMP for invasive species.		A	
Qualified professional applicator selectively herbicide invasive species		A	
Increase plant diversity by planting additional vegetation or creating a native plant infiltration basin area.		A	
Complaints from residents (note on back)		A	
Mowing done when necessary		A	
No fertilizer unless testing requires it		A	

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* Prior to field inspection, it is recommended to review the as-built plans.

Summary

Inspector's remarks:

____

____

Overall condition of facility (acceptable or unacceptable): ____________________________________

Dates any maintenance must be completed by: ____

Bioretention Inspection Checklist*

Project Location: ____

Date/Time: ____

Inspector: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Inlet/Outlet			
Structural integrity of inlet/outlet		A	
Inlet/outlet clear of debris		M	
Overflow spillway or catch basin clear of debris		M	
Erosion control at inlet in place (e.g., rock, mat)/ evidence of erosion		A	
Erosion control at outlet in place/evidence of erosion		A	
Inspect/clean catch basin upstream of BMP		Every 5 years	
Pretreatment for Sediment (Generally consists of catch basin or velocity dissipater at inlet such as area of riprap/collection for sediment			
Device functioning to trap sediment		A	
Remove accumulated sediment		A	
Overall functionality			
Ensure bioretention area is functioning properly (professional civil engineer is recommended)		A	
Bioretention area surface			
Evidence of sedimentation in BMP		A	
Does sediment accumulation currently require removal		A	
Debris in BMP		M	
Evidence of erosion present		A	
Does good vegetative cover exist?		A	
Mulch covers entire area (no voids) and to specified thickness		A	
Optional considerations			
Inspect BMP for invasive species.		A	

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* Prior to field inspection, it is recommended to review the as-built plans.

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Qualified professional applicator selectively herbicide invasive species		A	
Increase plant diversity by planting additional vegetation		A	
Complaints from residents (note on back)		A	

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* Prior to field inspection, it is recommended to review the as-built plans.

Summary

Inspector's remarks:

____

____

Overall condition of facility (acceptable or unacceptable): ____

Dates any maintenance must be completed by: ____

Bioswale, Filter Strip Inspection Checklist*

Project Location: ____

Date/Time: ____

Inspector: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Inlet/Outlet			
Structural integrity of inlet/outlet		A	
Inlet/outlet clear of debris		M	
Pretreatment / Energy Dissipaters			
No evidence of flow going around structures		A	
No evidence of erosion		A	
Device functioning to trap sediment		A	
Remove accumulated sediment		A	
BMP surface			
Area free of debris?		M	
No evidence of erosion		A	
Does sediment accumulation currently require removal?			

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* Prior to field inspection, it is recommended to review the as-built plans.

Maintenance Item	Satisfactory/ Unsatisfactory	Recommended Inspection Frequency	Comments
Overall functionality			
Ensure swale is functioning properly (professional civil engineer is recommended)		A	
Optional considerations			
Inspect BMP for invasive species.		A	
Qualified professional applicator selectively herbicide invasive species		A	
Increase plant diversity by planting additional vegetation		A	
Complaints from residents (note on back)		A	

Inspection frequency key — A = Annual, M = Monthly, S = After major storm
* Prior to field inspection, it is recommended to review the as-built plans.

Summary

Inspector's remarks:

____

____

Overall condition of facility (acceptable or unacceptable): ____________________________________

Dates any maintenance must be completed by: ____

Credits and Acknowledgments

This Appendix has been developed by Christopher B. Burke Engineering, LLC, and is primarily based upon similar segments contained in “Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers” published in 2009 by the Southeast Michigan Council of Governments (SEMCOG). A selection of material contained in the noted SEMCOG publication has been modified to reflect conditions in Indiana and used, with permission, for development of this Appendix. The valuable contribution of SEMCOG through sharing of this material for use in this Appendix is hereby acknowledged.

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Stormwater Management Practices Maintenance Agreement

Appendix D6

STORMWATER MANAGEMENT PRACTICES MAINTENANCE AGREEMENT

THIS AGREEMENT is made this ______________day of _______________ , 20____ , by and between the [Community Name], a municipal corporation, with principal offices located at [Community address], hereinafter "[Community]"and ____a ___________ with principal offices located ____, hereinafter "Owner".

[Owners Name], as "Owner(s)" of the property described below, in accordance with ____________ [Community Regulations], agrees to install and maintain stormwater management practice(s) on the subject property in accordance with approved plans and conditions. The Owner further agrees to the terms stated in this document to ensure that the stormwater management practice(s) continues serving the intended function in perpetuity. This Agreement includes the following exhibits:

Exhibit A: Legal description of the real estate for which this Agreement applies ("Property").

Exhibit B: Location map(s) showing a location of the Property and an accurate location of each stormwater management practice affected by this Agreement.

Exhibit C: Long-term Maintenance Plan that prescribes those activities that must be carried out to maintain compliance with this Agreement.

Note: After construction has been verified and accepted by the [Community Name] for the stormwater management practices, an addendum(s) to this agreement shall be recorded by the Owner showing design and construction details and provide copies of the recorded document to the [Community Name]. The addendum may contain several additional exhibits.

Through this Agreement, the Owner(s) hereby subjects the Property to the following covenants, conditions, and restrictions:

1. The Owner(s), at its expense, shall secure from any affected owners of land all easements and releases of rights-of-way necessary for utilization of the stormwater practices identified in Exhibit B and shall record them with the [Community] Register of Deeds. These easements and releases of rights-of-way shall not be altered, amended, vacated, released or abandoned without prior written approval of the [Community].

2. The Owner(s) shall be solely responsible for the installation, maintenance and repair of the stormwater management practices, drainage easements and associated landscaping identified in Exhibit B in accordance with the Maintenance Plan (Exhibit C).

3. No alterations or changes to the stormwater management practice(s) identified in Exhibit B shall be permitted unless they are deemed to comply with this Agreement and are approved in writing by the [Community].

4. The Owner(s) shall retain the services of a qualified inspector (as described in Exhibit C – Maintenance Requirement 1) to operate and ensure the maintenance of the stormwater management practice(s) identified in Exhibit B in accordance with the Maintenance Plan (Exhibit C).

5. The Owner(s) shall annually, by December 30th, provide to the [Community] records (logs, invoices, reports, data, etc.) of inspections, maintenance, and repair of the stormwater management practices and drainage easements identified in Exhibit B in accordance with the Maintenance Plan. Inspections are required at least after every major rain event.

6. The [Community] or its designee is authorized to access the property as necessary to conduct inspections of the stormwater management practices or drainage easements to ascertain compliance with the intent of this

Agreement and the activities prescribed in Exhibit C. Upon written notification by the [Community] or their designee of required maintenance or repairs, the Owner(s) shall complete the specified maintenance or repairs within a reasonable time frame determined by the [Community]. The Owner(s) shall be liable for the failure to undertake any maintenance or repairs so that the public health, safety and welfare shall not be endangered nor the road improvement damaged.

7. If the Owner(s) does not keep the stormwater management practice(s) in reasonable order and condition, or complete maintenance activities in accordance with the Plan contained in Exhibit C, or the reporting required in 3 above, or the required maintenance or repairs under 4 above within the specified time frames, the [Community] is authorized, but not required, to perform the specified inspections, maintenance or repairs in order to preserve the intended functions of the practice(s) and prevent the practice(s) from becoming a threat to public health, safety, general welfare or the environment. In the case of an emergency, as determined by the [Community], no notice shall be required prior to the [Community] performing emergency maintenance or repairs. The [Community] may levy the costs and expenses of such inspections, maintenance or repairs plus a ten percent (10%) administrative fee against the Owner(s). The [Community] at the time of entering upon said stormwater management practice for the purpose of maintenance or repair may file a notice of lien in the office of the Register of Deeds of the [Community] upon the property affected by the lien. If said costs and expenses are not paid by the Owner(s), the [Community] may pursue the collection of same through appropriate court actions and in such a case, the Owner(s) shall pay in addition to said costs and expenses all costs of litigation, including attorney fees.

8. The Owner(s) hereby conveys to the [Community] an easement over, on and in the property described in Exhibit A for the purpose of access to the stormwater management practice(s) for the inspection, maintenance and repair thereof, should the Owner(s) fail to properly inspect, maintain and repair the practice(s).

9. The Owner(s) agrees that this Agreement shall be recorded and that the land described in Exhibit "A" shall be subject to the covenants and obligations contained herein, and this agreement shall bind all current and future owners of the property.

10. The Owner(s) agrees in the event that the Property is sold, transferred, or leased to provide information to the new owner, operator, or lessee regarding proper inspection, maintenance and repair of the stormwater management practice(s). The information shall accompany the first deed transfer and include Exhibits B and C and this Agreement. The transfer of this information shall also be required with any subsequent sale, transfer or lease of the Property.

11. The Owner(s) agree that the rights, obligations and responsibilities hereunder shall commence upon execution of the Agreement.

12. The parties whose signatures appear below hereby represent and warrant that they have the authority and capacity to sign this agreement and bind the respective parties hereto.

13. The Proprietor, its agents, representatives, successors and assigns shall defend, indemnify and hold the [Community] harmless from and against any claims, demands, actions, damages, injuries, costs or expenses of any nature whatsoever, hereinafter "Claims", fixed or contingent, known or unknown, arising out of or in any way connected with the design, construction, use, maintenance, repair or operation (or omissions in such regard) of the storm drainage system referred to in the permit as Exhibit "C" hereto, appurtenances, connections and attachments thereto which are the subject of this Agreement. This indemnity and hold harmless shall include any costs, expenses and attorney fees incurred by the [Community] in connection with such Claims or the enforcement of this Agreement.

IN WITNESS WHEREOF, the ___________ and ________ have executed this Agreement on the day and year first above written.

WITNESSES:

__________________________________ By: __________________________________

__________________________________ Its: __________________________________

STATE OF Indiana)
) ss.
COUNTY OF County Name])

The foregoing instrument was acknowledged before me on this___________ day of _______________, 20 ___, by _____________________________________, the ______________________ of ___________________.

____

Notary Public

___________________________ County of Indiana My Commission Expires On:

[Community Name]
a municipal corporation

__________________________________ By: __________________________________

__________________________________ Its: __________________________________

STATE OF Indiana)
) ss.
COUNTY OF [County Name])

The foregoing instrument was acknowledged before me on this___________ day of _______________, 20 ___, by ______________________________________, the ______________________ of _____________________.

____

Notary Public

________________________ County of Indiana My Commission Expires On:

INSTRUMENT DRAFTED BY:

WHEN RECORDED RETURN TO:

[Community Name and Address]

Exhibit A – Legal Description

(Sample)

The following description and reduced copy map identifies the land parcel(s) affected by this Agreement.

Note: An example legal description is shown below. This exhibit must be customized for each site, including the minimum elements shown. It must include a reference to a Subdivision Plat, Certified Survey number, or Condominium Plat, and a map to illustrate the affected parcel(s).

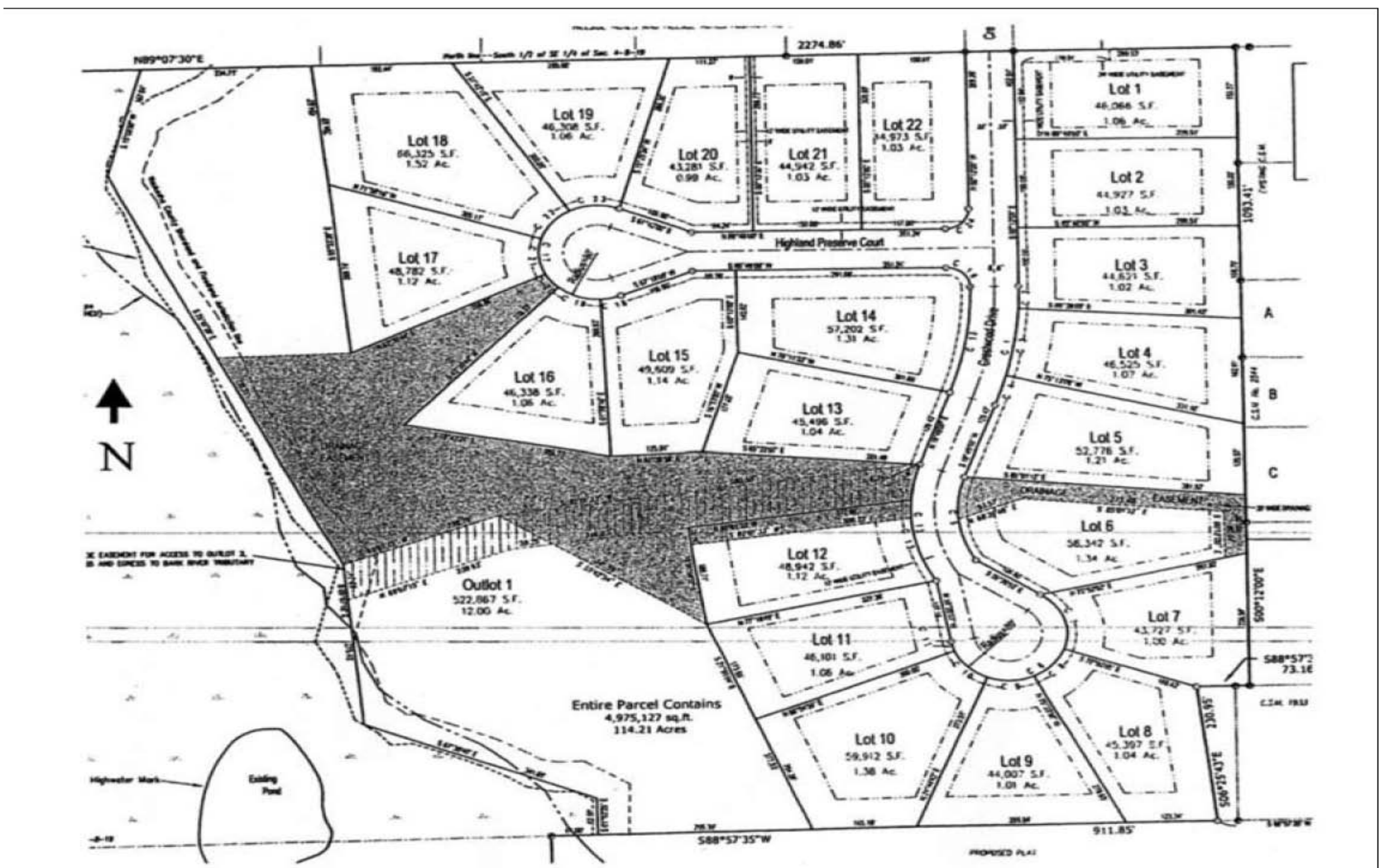
Project Identifier: Huron Preserve Subdivision

Acres: 40

Date of Recording: October 22, 2006

Map Produced by: ABC Engineering, P.O. Box 20, Green Oak Twp., MI

Legal Description: Lots 1 through 22 of Huron Preserve Subdivision, located in the Southwest Quarter (SW1/4) of Section 4, Township 8N, Range 19E (Green oak Township) Livingston County, Michigan. [If no land division is involved, enter legal description as described on the property title here.]



<u>Drainage Easement Restrictions:</u> Shaded area on map indicates a drainage easement for stormwater collection, conveyance, and treatment. No buildings or other structures are allowed in these areas. No grading or filling is allowed that may interrupt stormwater flows in any way. See Exhibit C for specific maintenance requirements for stormwater management practices within this area. See subdivision plat for details on location.

Exhibit B – Location Map

(Sample)

Stormwater Management Practices Covered by this Agreement

[*An example location map and the minimum elements that must accompany the map are shown below. This exhibit must be customized for each site. Map scale must be sufficiently large enough to show necessary details*.]

The stormwater management practices covered by this agreement are depicted in the reduced copy of a portion of the construction plans, as shown below. The practices include on wet detention basin, two forebays, two grass swales (conveying stormwater to the forebays) and all associated pipes, earthen berms, rock chutes, and other components of these practices. All of the noted stormwater management practices are located within a drainage easement in Outlot 1 of the subdivision plat as noted in Exhibit A.

Subdivision Name: Huron Preserve Subdivision

Stormwater Practices: Wet Detention Basin #1, forebays (2), grass swales (2)

Location of Practices: All that part of Outlot 1, bounded and described in Figure B.1: [If no land division is involved, enter a metes and bounds description of the easement area.]

Titleholders of Outlot 1: Each Owner of Lots 1 through 22 shall have equal (1/22) undividable interest in Outlot 1 [For privately owned stormwater management practices, the titleholder(s) must include all new parcels that drain to the stormwater management practice.]

Figure B.1 Plan View of Stormwater Practices

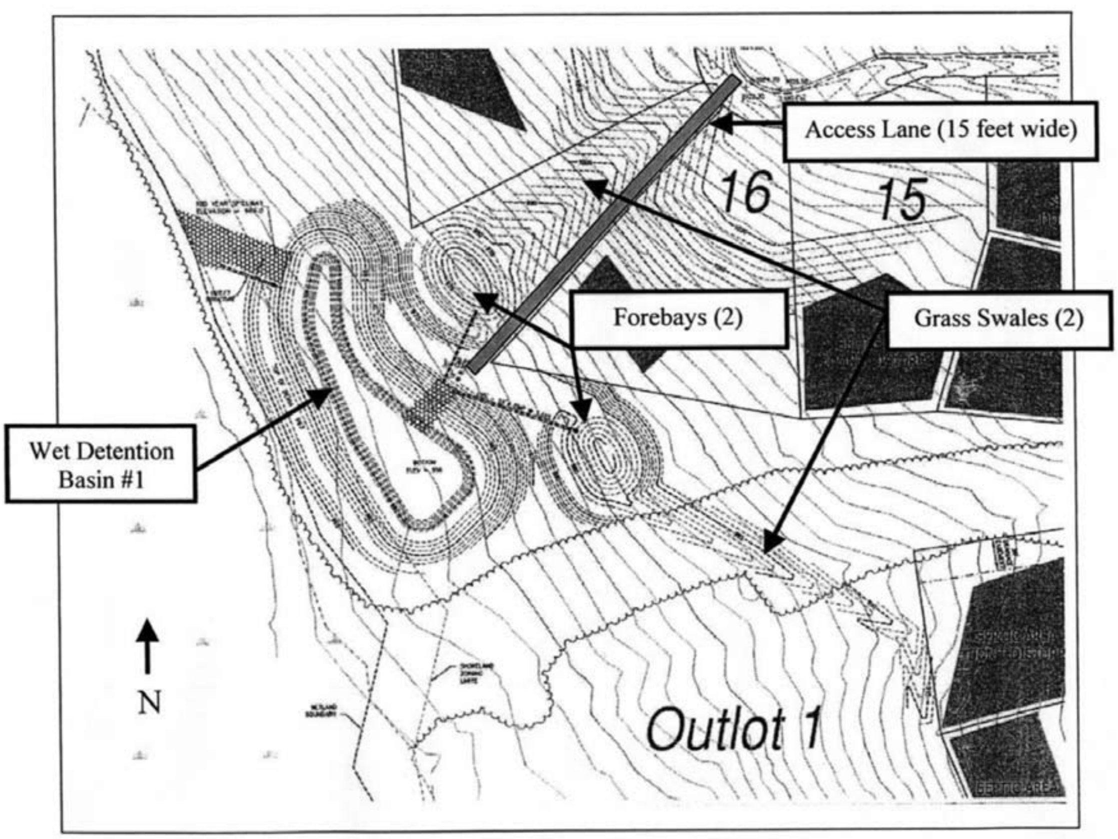


Exhibit C - Stormwater Practice Maintenance Plan

This exhibit explains the basic function of each of the stormwater practices listed in Exhibit B and provides the minimum specific maintenance activities and frequencies for each practice. The maintenance identified by the Owner should follow the maintenance activities listed in this manual, if applicable. Vehicle access to the stormwater practices is shown in Exhibit B. Any failure of a stormwater practice that is caused by lack of maintenance will subject the Owner(s) to enforcement of the provisions listed in the Agreement by the [Community].

The exhibit must be customized for each site. The minimum elements of this exhibit include: a description of the drainage area and the installed stormwater management practices, a description of the specific maintenance activities for each practice which should include in addition to specific actions:

- Employee training and duties,
- Routine service requirements,
- Operating, inspection and maintenance schedules, and
- Detailed construction drawings showing all critical components and their elevations.

References

Charter Township of Canton, Stormwater FACILITIES MAINTENANCE AGREEMENT.

Charter Township of Green Oak, AGREEMENT FOR MAINTENANCE OF STORMWATER MANAGEMENT PRACTICES

Credits and Acknowledgments

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